University of Alberta

The Twin Block Appliance - A cephalometric analysis of vertical control

by

Dr. Colleen Ann Adams ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of
the requirements for the degree of Master of Science

in

Orthodontics

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Abstract

This study investigates the twin block appliance's ability to correct overbite. Lateral cephalometric radiographs at time-1 and time-2 were scanned and digitized for patients treated with the twin block appliance and a control group. The twin block group was divided based on different treatments for the correction of overbite. The deep bite treatment group experienced overbite correction of 4mm while the open bite treatment group did not change significantly from the control group. Regression analysis identified the most important variables in the overbite correction for the deep group as increased lower face height of 2.5mm, downward movement of pogonion and gnathion by 2.0mm, restriction of mandibular incisor eruption by 1.7mm and proclination of the lower incisor by 4.5 degrees. Comparison of the two treatment groups showed that there was no difference in the anteroposterior correction; both groups finished treatment with ANB angles of 4 degrees and overjets of 2.2mm.

University of Alberta

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled The Twin Block Appliance - A Cephalometric Analysis of Vertical Control submitted by Dr. Colleen Ann Adams in partial fulfillment of the requirements for the degree of Master of Science in Orthodontics.

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Dedication

This thesis is dedicated to the memory of my grandfathers. Their curiosity and academic interest has been an inspiration for the whole family and they are felt with me in all things challenging. A special thank-you to my parents and to my husband for all their unquestioning encouragement and support.

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Introduction

1.1 Research Problem

Functional appliance therapy and the treatment of vertical problems are both current areas of interest in orthodontics. Functional appliance therapy is controversial in its ability to produce real and stable skeletal changes. There are many conflicting reports in the literature. Some investigators contend that these appliances produce dramatic and stable results while others have found little difference over normal growth. The vertical dimension is an area of orthodontics that is difficult to manage clinically and the treatment options available are somewhat limited. This study investigates the ability of the twin block appliance to correct vertical problems in open bite and deep bite cases. The current literature on the twin block appliance has been focused on the achievement of anteroposterior correction of malocclusions and the ability of this functional appliance to produce vertical corrections has not been fully explored.

The vertical aspect of malocclusions is often difficult to correct from a mechanical point of view for both extremes of deep and open bites. Treatment options are limited for vertical problems and once treated, vertical discrepancies are also subject to higher relapse rates than other orthodontic corrections. It may prove that growth modification is the best method for achieving stable results.

Growth modification with functional appliances is still a controversial topic despite their use since the beginning of the century. The issues debated surround the existence of an actual alteration of skeletal growth to correct the skeletal discrepancy. In Class II treatment this debate is largely whether increase of mandibular length occurs and whether the long term result represents the same total growth as would have occurred without treatment. Most investigators show evidence of positional changes of the mandible. These results may represent actual increase in the size of the mandible, or remodeling of the temporomandibular joint in a more forward position or muscular positioning of the mandible in a forward posture. The basis of the correction is the issue. Muscular posturing as a mechanism for correction would not be thought to be stable in the long term. Remodeling of the temporomandibular joint to a more anterior position may or may not be desirable in any individual case. Increase in mandibular growth causing the mandible to become larger relative to the rest of the face is the most favorable explanation but it is still questionable whether the increased growth is maintained with normal growth rates after treatment. It is difficult to ascertain that the mandible has actually increased in length because on lateral cephalograms the condyle is very often obscured by structures of the cranial base so it becomes difficult to measure mandibular length accurately. To further complicate the issue the observed changes may also be due to a combination of some or all of these methods.

Long term properly randomized clinical trials are required to provide the concrete answers to some of these problems, if they can be proven at all. It is valuable though to investigate the effects of treatment with the Twin Block appliance as it has recently been gaining popularity and showing some good clinical results in Phase I treatment. Hopefully investigating the changes that occur as the immediate effects of treatment will increase understanding of the method of action of this appliance.

The Twin Block appliance is similar to many other functional appliances in holding the mandible in a forward position to appreciate an anteroposterior change. It is by design also able to address the vertical and transverse aspects of the occlusion. It is the purpose of this study to focus on the vertical control ability of this appliance. The relationship of vertical changes and anteroposterior correction will be commented upon.

1.2 Functional Appliance History

Functional appliance therapy is a current area of interest in the North American orthodontic community. These appliances are used to guide facial growth and allow dental development. Functional appliances have been used for a long time in Europe. They have provided an affordable way to correct or improve even severe dentofacial deformities. In North America there has been much skepticism of functional appliances but opinions have slowly been changing and these appliances have enjoyed increasing use and popularity over the past twenty years. (Proffit, 1993)

Many designs have been used but the main feature of these appliances is posturing of the mandible in a more favorable position. The functional matrix theory of Moss (1969) would suggest that creating functional forces in this position should stimulate the craniofacial growth centers to accommodate with alteration in form. It is believed that to maximize the potential for skeletal changes in growth the appliance design should minimize contact with the teeth. Posturing the mandible requires muscular activity. As the muscles fatigue the jaw tends to lean on the appliance. This creates forces which tend to move the teeth to camouflage the skeletal discrepancy. The advantage of using a removable appliance is that the design of acrylic extensions allow the possibility of large areas of mucosal contact. The contact on the mucosa can help absorb some of the forces as the muscles fatigue and therefore reduce the forces experienced by the teeth. The less orthodontic alteration that occurs the greater the potential for orthopedic effects.

Most functional appliances can be constructed to posture the mandible forward for Class II correction or create posterior pressure pushing the mandible back for Class III correction. In the discussion of appliances that follows, the Class II designs will be described. Many functional appliances also incorporate design features to alter pressures experienced by individual teeth to accomplish limited tooth movements. These modifications can be tailored to individual cases as required.

Functional appliance treatment has been proposed by individuals since early this century or even the late 19th century. Over time there has been an evolution in designs. Catlan from Spain and Kingsley in the United States both used an inclined anterior bite plane to induce the mandible to assume a forward posture and "jump" the bite. Robin in 1902 advocated the monoblock appliance to expand the upper and lower arches and posture the mandible forward with a single removable appliance. By 1910, Andresen had developed his appliance which is derived from the one piece monoblock design with inclined planes along the lingual flanges that the teeth slide along to guide the mandible into protrusion. (Ahlin et al, 1984)

The activator is a derivative of the Andresen appliance and was probably most popularized by Harvold (Harvold, 1974). The main modifications of this appliance are: acrylic capping of the lower incisors, extension of the lingual flanges to contact as much of the mucoperiosteum of the mandible as possible with smooth surfaces and considerable occlusal bite shelves which are flat to the cusp tips.

In the 1950's and 60's other examples of removable one piece appliances were introduced including: the bionator and the Frankel. The bionator is a smaller version of an activator. This appliance was developed by Balters. An acrylic lingual flange is used to guide the mandible with a wire labial bow and buccinator bow often included in the design. (Proffit, 1993) The Frankel appliance differs from the other functional appliances in design and philosophy. It is made to contact mucosal surfaces with only minimal tooth contact. Acrylic shields in the vestibule are constructed to remove the lower lip, and cheek pressures which allows expansion into these areas. The lingual acrylic flange contacts the mucosa lingual to the lower incisors posturing the mandible forward. The acrylic shields are connected with wires. (Frankel, 1982)

Functional appliances have commonly encountered problems with cooperation as they are generally very bulky and interfere with speech. Children find them difficult to accommodate to and most designs must be removed for eating. This often lead to part-time wear schedules recommended for many of the appliances.

Recently a new generation of fixed functional appliances has become popular. This avoids the issue of compliance. These appliances are more streamlined than the removable types and do not interfere with speech. Some examples include the Herbst, Mara, and Jasper Jumper. The Herbst appliance has been studied most extensively by Ruf and Pancherz. The main disadvantage with these appliances is that they are attached only to the teeth. Consequently the dentition is exposed to greater forces and is far more likely to displace. The greater displacement of the teeth limits the skeletal correction which may be generated.

The design of the twin block appliance is a system of two interlocking plates and has been most promoted by Clark since 1982. The maxillary appliance is constructed with palatal coverage and clasps for retention. The mandibular appliance has a lingual flange at the anterior and also clasps the teeth. The two pieces fit together via bite blocks covering the occlusal surfaces of the posterior teeth. The bite blocks meet along an inclined plane of approximately 70 degrees. It is this fit along the inclined plane that postures the mandible forward. The bite blocks present in this design allow convenient adjustment for vertical changes to occur simultaneously with anteroposterior changes. This appliance is reported to be better tolerated than the other removable functional appliances as it interferes less with speech and allows nearly a full range of mandibular movement.

All of these appliances hold the mandible in a forward posture but they differ in key ways. Appliance bulk, ease of accommodation, degree of vertical control and impact on the dentition are essential considerations in appliance selection.

1.3 Functional Appliance Research in Animals

The research on functional appliances is voluminous. In the past few decades a quantity of research has examined the effects of changes to the functional environment on the growth of the mandible in animals. These studies used rats and monkeys with functional appliances that were fixed in place for varying periods of time. Monkey experiments by Baume and Derichsweiler(1961), Elgoyhen et al (1972) and Woodside et al (1983, 1987) have all demonstrated condylar growth in response to forward positioning splints. Hinton and McNamara (1984) showed temporal bone adaptations, specifically deposition of bone, in the posterior of the glenoid fossa in juvenile monkeys in response to protrusive function. Meikle (1970) investigated use of intermaxillary force applied to fixed splints in monkeys. He found significant dentofacial changes but minimal change at the temporomandibular joint.

Some other relevant studies examine the changes that other functional alterations to the masticatory system, apart from fixed appliances, can produce in animals. Ghafari and Heeley (1982) performed a study of condylar adaptation to alteration of muscle function in rats. They detached the masseters and repositioned them or left them to heal on their own and found that changes in condylar morphology occurred rapidly. Conversely work by Awn, Goret-Nicaise and Dhem (1987) showed no changes in condylar growth after sectioning of the lateral pterygoid muscle unilaterally in rats.

Animal experiments have also demonstrated dental and skeletal changes in response to function with bite blocks that do not alter anteroposterior position. A 1995 study by Ferrari and Herring showed intrusion of maxillary and mandibular posterior teeth and supraeruption and retroclination of anterior teeth in pigs wearing bite opening appliances over a period of approximately eight weeks. They also found changes in condylar morphology and temporomandibular joint disc remodeling. Melsen, McNamara and Hoenie also (1995) showed evidence of skeletal changes in the maxilla with bite blocks placed in monkeys for twenty-four weeks.

The evidence of skeletal changes which occur in animals when forced to function in altered positions is compelling. Petrovic (1985) states that the increase in mandibular lengths demonstrated in his animal research is stable in the long term if the functional appliances are removed after the growth of the animal is complete or if there is good intercuspation. Based on the these results the possibility of using these techniques to alter human growth and thereby facial pattern seems enticing.

1.4 Functional Appliance Clinical Investigations

There have been many studies which attempt to reveal such treatment effects of these appliances on human subjects. A selection will be reviewed.

Baumrind and associates (1983) reported the results of superimpositional cephalometric analysis of 238 cases of Class II subjects. Their superimpositions were designed to examine only the changes in the mandible. The sample was divided approximately evenly between three treatment groups and a control group . The treatment groups were cervical headgear, highpull headgear, and activator. They found that cervical headgear and activator groups experienced increased growth rate of the mandible and the activator produced significantly greater forward displacement while the cervical headgear produced significantly greater downward displacement. The third treatment group - high pull headgear - showed no statistically significant difference in mandibular growth rate or direction from the control group.

In 1985 McNamara, Bookstein and Shaughnessy looked at changes in the growth of 100 patients treated with Frankel functional regulators. McNamara and colleagues found that advancement of the mandible did occur in amounts averaging 3mm of increased length. This was not all expressed as forward movement, in fact approximately two thirds of the increase was vertical and demonstrated as increased lower face height. There was little effect on the maxilla but the maxillary molars did show a decreased forward movement and the maxillary incisors tipped distally an average of 2mm. The mandibular molars had increased eruption and the mandibular incisors showed minimal anterior tipping. This was a retrospective study from private practice records of patients that had been deemed to have cooperated. The authors state this assessment was not based on the success of the treatment but by report from parents and objective tissue signs. Their control group was a Class II group matched for age.

Later in 1985, Vagervik and Harvold published a prospective study including 83 subjects treated with activator appliances. They matched controls for age and sex for thirty six of their sample subjects. They also compared longitudinal changes from the pretreatment growth of the sample group. From the thirty-six matched pairs analysis they found inhibition of maxillary growth, uprighting of the maxillary incisors, leveling of the mandibular occlusal plane, downward and forward relocation of the glenoid fossa, advancement of all mandibular structures and increased lower face height. Oblique lateral films were taken at the same time as the lateral cephalograms and there were deemed to be no changes in condyle position within the fossa in any subjects.

DeVincenzo, in 1987, investigated a functional appliance constructed after the protrusive jaw positioning apparatus used in the monkey experiments. The description given is similar to the twin block in that it is comprised of two removable bite plates separated by a vertical interface that only allows closure in protrusive mandibular position. He had thirty-five consecutively treated cases and compared them to controls matched for age, sex and mandibular plane angle to SN. The control group was mainly Class II with approximately one third having some phase I treatment. He also compared the growth rates to the published standards from the Michigan, Bolton and Burlington studies. His results showed significant increases in growth rates for the mandible as measured from articulare. The dentoalveolar changes included posterior movement of the maxillary incisors (tipping) and mesial migration (tipping and possible bodily movement although these were not quantified with a tooth axis) of the mandibular dentition. He estimated an increase of 2.2mm in mandibular growth over the normal expected amount for the average 9.4 month treatment time. DeVincenzo then followed up this study in 1991with a long term study. He assessed the effects of functional appliance treatment for the same group as in the previous study, two and four years after the completion of the therapy. He selected those who had best responded to phase I treatment. During the post functional appliance time the subjects received full edgewise treatment. They were compared with matched controls from the Burlington growth study. The control group was selected based on age, sex and mandibular plane angle as in the previous investigation. In the control group unfortunately approximately seventy percent had some form of growth modification treatment before being used in this control group. (26% bite planes, 23% cervical headgear, 21% monoblock). The data suggest that despite early treatment success with the functional appliance under investigation after four years there was no difference between the treatment and "control" groups. The rate of growth of the mandible slowed significantly from the observed functional appliance treatment spurt and the overall resulting dimensions achieved were not significantly different. The author speculates that possibly the more orthopedic changes obtained, the more potential for relapse.

In 1993, Nelson, Harkness and Herbison published a prospective clinical trial with a control group and two treatment groups. The entire sample of forty-two children with Class II div. I malocclusions were matched in triads for age and sex and then randomly assigned to one of the three groups. One treatment group used a Frankel appliance and the other a Harvold activator. It should be noted that the appliances used differed markedly in their degree of activation. The Harvold activators were constructed such that the bite was opened 10.5mm and advanced 7.0mm on average while the Frankel appliances were fabricated to 6.4mm vertically open and 4.8mm advanced on average. The results were analyzed after eighteen months. They found significant increases in the gonial angle and in the articulare to pogonion length in the activator group. They attribute this to a downward and forward position of the mandible. They did not demonstrate any increase in the overall mandibular length as measured from condylion. The articulare to pogonion length also significantly increased in the Frankel group yet again no difference in the condylion to pogonion length could be demonstrated. Both treatment groups had increased eruption of lower first molars that significantly correlated with increased anterior face height. They conclude that there was no evidence to support claims of increase in mandibular length from functional appliance treatment.

A study in 1993 by Windmiller was based on an acrylic-splint Herbst removable appliance. This appliance used a Herbst mechanism to connect two separate acrylic splints. The splints fit over the maxillary posterior dentition and the entire mandibular dentition but did not extend over the mucosa. Forty-six subjects were selected from available records according to specific exclusion criteria (not given in the article). The control group was the same Class II group from the McNamara, Bookstein and Shaughnessy study, selected for age and extrapolated for a twelve month period. The study subjects were then classified by FH to MP <23 for horizontal 23-28 for normal and >28 for vertical facial patterns. Their results showed correction to Class I post treatment with no change in the vertical skeletal pattern. They found significantly more growth of the mandible - as measured from condylion to gnathion - than in the untreated Class II control and significantly less forward maxillary growth as well. They also found that vertical pattern cases had greater correction of Class II indicators (ANB, SNB, maxillomandibular differential). This study found no significant change in the sagittal position of the condyle.

There is a phase I treatment study under way at the present time in North Carolina (Tulloch, Phillips, and Proffit, 1997, 1998). They are using a prospective randomized design for this clinical trial with groups consisting of combination headgear, bionator and control(no treatment). This is a large scale study with 166 patients completing phase I. These patients were assigned to either headgear, bionator or control groups. The results of the treatment were evaluated at 15 months. The headgear and bionator treatment groups showed an improvement in the skeletal discrepancy after phase I. The headgear group had a greater tendency for restricted maxillary growth while the bionator group had improved mandibular length and chin position. The authors are quick to stress that there is great variability in the responses with about a seventy-five percent chance that the individual will respond favorably to such early treatment. Some preliminary results have been published after completion of both phase I and phase II treatment (107 patients having completed both stages of treatment) and they show very little difference between the three groups in parameters such as mandibular length and ANB angles. It is found that the degree of skeletal discrepancy is not significantly different between the three groups and the changes in dental occlusion were also similar between the groups. There were some differences in the consideration for surgery as an option for phase II. This option was considered more often in the control group and least often for the functional appliance group but the authors suggest this might also be due to some bias in consideration of the severity of the malocclusion in the control group and the lessened available growth time due to the later start treatment age for this group.

The literature shows that short term studies of growth modification seem to provide good treatment outcomes with skeletal and dental contribution to the corrections but the longer studies are less than compelling. It may be that growth modification changes make only temporary differences in growth and the genetic propensity for growth of any area of the face fulfills its potential regardless of temporary environmental alterations. If this is true then perhaps growth modification does not really occur in the long term. To provide the best chance at permanent change it may be that growth modification should be maintained throughout the period that the patients are growing to continue the stimulus for a higher growth rate and maintain the skeletal correction.

1.5 Twin Block Clinical Investigations

The Twin Block is a recently popularized removable functional appliance which Clark has written extensively about over the last two decades. In his 1995 textbook, he claims to have performed clinical trials and gives results compared to an age matched control group but provides no methods or data. As described previously, the basic design of the appliance is a two piece system of bite blocks with sloping vertical ramps that encourage forward positioning of the mandible. This appliance is intended for full time wear, even during eating. This would be impossible with the other removable functional appliances. Full time wear of this nature would be expected to produce greater changes over shorter periods of time analogous to the fixed style appliances with the advantage of the acrylic to mucosal coverage to increase the orthopedic effects. The compliance with the twin block has been reported to be very good, due in part to the inconspicuous nature of the design and the lack of impact to daily activities such as eating and speech.

Previous studies by Lund and Sandler (1998) as well as Mills and McCullough (1998) have shown this appliance to be an effective method for correction of Class II malocclusions. The Lund and Sandler study was a controlled prospective study. The treatment group consisted of thirty-six patients and the control group 27 patients awaiting orthodontic treatment. Both the treatment and control groups were determined to meet the following inclusion criteria; skeletal and dental Class II, 10-14 years of age and Caucasian. The appliances were fabricated with 7-8mm of protrusion and 6-7mm of vertical opening. Pre and post treatment cephalograms were measured to determine the source of the corrections. The Mills and McCulloch study was a retrospective analysis of 28 consecutively treated cases. The treatment group met selection criteria for skeletal and dental Class II malocclusion. The control group, also 28 cases, was selected from available records at the Burlington Growth Study, matched for overbite depth, age and sex. Unfortunately due to the limited records of untreated individuals, the control group was statistically significantly less Class II than the treatment group. Appliances were made to a construction bite of approximately 6mm protrusion and 5mm of vertical opening. Pretreatment and post treatment lateral cephalograms were measured and compared to the measured time 1 and time 2 radiographs for the control group.

These studies had relatively similar findings. They demonstrated reduction of overjet, increase in SNB, decrease in ANB, and improved molar relationship. Both studies show that these corrections are effected partially by means of dentoalveolar change with some skeletal contribution. The degree of skeletal versus dental contribution to the overall correction is quite different between the two studies. The appliance design between the two studies may have contributed to the discrepancy in the degree of dental versus skeletal changes seen. The Lund and Sandler study used appliances incorporating a maxillary labial bow and constructed them with 1-2 mm more protrusive and vertical activation. The Lund and Sandler study showed relatively large changes in incisor angulations. Maxillary incisors retroclined on average 10.8 degrees and mandibular incisors proclined 7.9 degrees. The Mills and McCulloch study reported that the maxillary incisors of their treatment group only retroclined 2.5 degrees on average and the mandibular incisors proclined 5.2 degrees. It is not surprising then to find that the two studies reported different amounts of skeletal changes. Lund and Sandler found small skeletal effects - on average a 2.4mm increase in mandibular length from articulari to pogonion, while Mills and McCulloch showed 4.2mm of increased mandibular length. The Mills and McCulloch study also demonstrated an inhibition of maxillary forward growth while the Lund and Sandler study showed no effect here.

Another prospective clinical trial has been reported by Illing, Morris and Lee (1998). They compared the Twin block appliance to the Bass appliance with high pull headgear and the bionator. They had forty-seven patients assigned to the three groups and an untreated control group of twenty patients. They conducted the study over nine months of treatment time. The treatment and growth effects were measured from pre and post treatment cephalograms. There were differences in the design of the appliances and the amounts of initial activation incorporated. The correction of the malocclusions was not complete for all subjects at the time of analysis. The skeletal findings include statistically significant increases in mandibular length produced by both the twin block and bionator appliances. The twin block group showed a restriction of the forward movement of point A and downward tipping of the maxillary plane. Lower face height was also increased for all of the appliances used compared to the control group. They state that the increase in lower anterior face height "was the most marked facial change found in the study". They further propose that future studies should be constructed with groups subdivided according to facial height.

The Illing, Morris and Lee study also showed dental changes with the twin block group demonstrating 9.1 degrees of retroclining for the maxillary incisors and 2 degrees of proclining of the lower incisors (note: This value was not significantly different from the control group which retroclined 1.7 degrees). The bionator group showed statistically significant changes for tooth angulations with maxillary incisors retroclining 7.6 degrees and mandibular incisors proclining 4.0 degrees.

These investigators state that they perceive the twin block appliance to be the most effective in this study at producing the saggital and vertical changes required for correction of Class II malocclusions. They make this conclusion based on their observation that the twin block appliance produced the greatest amount of anterior movement of the mandible as well as the greatest increase in lower facial height.

In December 1999 a new study by Toth and McNamara looked retrospectively at the effects of Twin-block and Frankel FR-2 appliance therapy. They compared the lateral cephalograms of one hundred and twenty cases, forty in each treatment group and forty in a control group. The treatment and control groups were matched for age and sex. The measurements of treatment changes were standardized to the sixteen month treatment time of the Twin-block group. They found that the Twin-block and Frankel appliances both produced similar effects in correction of the Class II condition. They reported statistically significant increases in mandibular length of 3.0mm for the Twin-block group and 1.9mm for the Frankel group. They did not find significant inhibition of maxillary growth in either treatment group. There were greater dentoalveolar changes apparent in the Twin-block group which was expected as this appliance is tooth borne unlike the Frankel. This study does indicate the need for further investigation of the vertical effects of the Twin-block appliance. They report the vertical changes with generalized increases in vertical development in both the Twin-block and the Frankel patients but it is noted that the Twin-block patients were treated differently based on the requirement to increase or decrease vertical development in individual cases.

No studies of the twin block thus far have addressed the effects of this appliance on differing vertical facial patterns. Authors of the previously reviewed articles do mention the ability of the appliance to be used in this manner but have not divided their treatment groups to look at this aspect. The bite blocks offer a convenient method for changing the vertical constraints on the dentition. In vertical or open bite cases the bite blocks are left full height. In deep bite cases the posterior (maxillary) blocks are trimmed to allow differential eruption of the mandibular molars. The eruption of the mandibular molars also improves their anteroposterior relationship to the maxillary molars. This would suggest that the molar relationship might be more difficult to correct for the vertical cases. This might be reflected in increased treatment times. Unlike some other Class II correction methods though, the prevention of maxillary molar eruption afforded by the presence of the bite blocks offers the possibility of A-P correction without autorotation of the mandible distally.

1.6 Discussion of Vertical Facial Pattern

The impact of vertical considerations was clearly described by Sassouni in 1969. He stressed the need for orthodontists to consider the four bony planes of the face (supraorbital, palatal, occlusal and mandibular) and their relationship to each other. In a patient with abnormal vertical proportions these planes, if extended on the tracing, will intersect at a point behind the face that is either very close as in open bites or far away as in deep bites. The etiology of these disharmonies appears to be multifactorial. In 1969 Richardson reported that increased lower face height was correlated with the open bite cases and the jaw angles and joint angles were also significantly larger in the open bite patients. His study included 110 subject pairs (open/deep cases) matched for age and sex. Nahoum in 1971 studied open bite versus normal cases and found that the palatal plane had a significant effect. If the palatal plane was canted upward in the anterior it would cause a decreased upper face height with a correspondingly increased lower face height. Isaacson and colleagues also in 1971 studied a group of patients selected by steep mandibular plane angles. They reported that they found three morphologically causative factors for the development of a steep mandibular plane: increased height of the posterior alveolar process of the maxilla, decreased mandibular ramus height, and increased height of the mandibular posterior alveolar process. Schendel et al in 1976 studied the morphological differences between open bite high mandibular plane cases and non-open but still high mandibular plane cases. They found that the ramus height was increased - actually above normal - in the closed cases. They also agreed with Isaacson's study finding an increased dimension of the posterior alveolus of both jaws for the open cases.

Observations have been made by Sassouni and others that vertical pattern patients seemed to have decreased bite force compared to the horizontal patients. In 1980, Throckmorton, Finn and Bell used a two dimensional model to calculate the mechanical advantage of the temporalis and masseter muscles to see if this might explain some of these observations. They showed that increasing the maxillary height and the gonial angle both reduced the mechanical advantage of these muscles. The reduced ramus height also reduced the mechanical advantage of temporalis but increased the advantage of masseter. The morphological differences observed in the vertical dimension are influential in the amount of force that can be generated by the muscles of mastication. The fact that muscular function is altered by vertical pattern suggests a link in form and function but it is impossible to determine which if any factor is causative. Does the genetically determined pattern result in limited muscular ability or does decreased muscle function encourage altered growth and change the morphology of the bony structures?

It would seem that patients may present with disharmony in one or a number of areas that cause a skeletal anterior open bite. The ability to address the problem may depend on the particular area involved for that patient.

The orthodontic methods available for treatment of vertical problems are somewhat limited. Schudy, in 1968, examined the control of overbite. He suggests that the objective in deep bite cases is to move all the molar teeth occlusally and avoid intruding the lower incisors. Thompson (1979) supports this advice finding that lower molar extrusion showed no relapse but lower incisor intrusion relapsed by 50%. Often this may be accomplished with use of a removable bite plane that allows differential eruption of the mandibular molar teeth. Pearson in 1978 examined vertical control for patients with vertical growth tendencies. He recommends using extractions, high pull headgear and vertical pull chin cups. Proffit (1993) recommends the use of functional appliances with bite blocks covering all the posterior teeth that is made to a vertical dimension exceeding the patient's normal freeway space. If the patient has a severe skeletal open pattern or is past growth, surgery is often the only adequate solution.

There are relatively few studies of appliances for vertical control. A recent article by Iscan and Sarisoy (1997) examined the effects of placing posterior passive bite blocks of varying thickness in patients with skeletal open bites. Patients were selected with mandibular plane angles (to SN) of 37degrees or more and negative overbite with no recent history of a sucking habit. Two treatment groups (n=13,12) and one control group (n=14) were matched for age and sex. The treatment groups were then given the passive acrylic positioning appliances constructed to 5mm of vertical height for one treatment group and 10mm for the other. The patients in the treatment groups were instructed to wear their appliances 18 hours per day. The results showed an improvement in overbite with both treatment groups; the mandible rotated upward and forward. This differed from the control group which continued to grow in a downward and backward rotational pattern. The thickness of the blocks could be shown to affect the gonial angle and the ramal inclination with larger changes in these angles occurring with the larger bite opening. Interestingly, there was little difference in treatment time between the two groups and the reduction of open bite was comparable.

Uner and Yucel-Enoglu (1996) used a splint with anterior high-pull headgear for phase I treatment of Class II div I patients. They stated that the bite block effect of the splint caused an anterior rotation in the growth of the mandible with condylar growth direction change from backward to upward. The study had small sample size and no way of distinguishing the effects of the headgear from the splint effects.

1.7 Research Recommendations

Orthodontics has been practiced since the beginning of the century and gained huge popularity in public demand. Many of the techniques are obviously very successful in producing desired changes but scientific analysis of the variety of techniques employed by the profession is lacking. Baumrind (1988) discusses that many widely held beliefs pervade the profession without substantive scientific support. He suggests more research should be aimed at determining exactly which areas of the craniofacial complex we are influencing and to what degree. In 1990 Tulloch, Medland and Tuncay reviewed articles from 1980 to 1987 on the treatment of Class II malocclusions. They felt that much of the research they reviewed was not well designed or reported and did not provide readily comparable results from one study to another. This resulted in much uncertainty over the validity of the investigated techniques. They produced some recommendations as to the design and reporting of future studies. Some of their suggestions included; evaluation of the treatment and control groups for pretreatment equivalence, full disclosure of inclusion and exclusion criteria, mention of where and by whom the treatment was performed, completion criteria for treatment, appropriate statistical analysis including an estimate of type II error and randomization of prospective studies. These important parameters will allow a better understanding of the tools we are using and the variability of response that we are likely to encounter.

One aspect of scientific assessment of treatment outcomes is the objectivity of measurement of lateral cephalometric radiographs. Baumrind(1988) suggests a grid format for analysis of lateral cephalometric landmarks in horizontal and vertical planes with superimposition at the anterior cranial base. The coordinates are parallel to time 1 anatomic Frankfort horizontal plane and the origin is place at the time 1 point of interest. Mamandras and Allen used a similar reference structure in their 1990 study of Bionator patients. They measured landmarks on the lateral cephalograms to a constructed Frankfort Horizontal reference, eight degrees from anatomic SN. This adjustment removes the error associated with the difficult landmarks required for anatomic Frankfort Horizontal but provides a reproducible horizontal reference. The vertical reference is then perpendicular through sella. This method has since been repeated in an investigation by Ellen, Schneider and Sellke (1998) examining treatment effects with Class II fixed appliance therapy and Illing, Morris and Lee (1998) used this method to asses their lateral cephalolgrams in evaluating the functional appliances discussed earlier. These two studies chose to use their constructed FH as seven degrees from SN.

Current investigations are striving to meet scientific criteria to create solid evidence for treatment procedures and dispel some of the popular myths which may limiting the effectiveness of orthodontic practice.

1.8 Statement of Objectives

It is the object of this study to assess the Twin Block functional appliance in its ability to create favourable skeletal and dentoalveolar changes in vertical dimension in moderate to severe Class II division I patients. The recommendations as described in the Tulloch, Medland and Tuncay paper are followed as much as possible in this study. The retrospective nature of this project presents some limitations to ideal experimental design, these will be explored in the individual papers and in the general discussion.

Analysis of pre and post treatment lateral cephalograms provides the data. The changes in the anteroposterior and vertical position of the incisors, molars and the jaws are examined. These landmark measurements are taken from a constructed reference coordinate system following the design of Mamandras and Allen (1990). Pilot studies were performed to ensure the accuracy of the methods. There are two treatment groups based on the treatment they received. The open bite group had treatment with bite blocks remaining at full height of approximately 5mm. The deep bite group had the maxillary bite block reduced at each visit to allow eruption of the posterior mandibular teeth. The treatment groups are compared to a control group to determine the changes attributable to growth versus those due to appliance wear. The control groups were selected to match the treatment groups according to age, sex, vertical skeletal pattern and severity of Class II from the available records at the Bolton-Brush Growth Study Center. Dental and skeletal effects are examined to determine their relative contribution to the observed treatment effect. A comparative observation is made between the two treatment groups as to the outcomes of cases, especially with respect to post treatment overbite and overjet.

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Chapter 2

Pilot Study I

Scanned Radiographs Using Custom Cephalometric Analysis

2.1 Introduction

This pilot study was undertaken to investigate the reproducibility of the measurement of distances and angles with scanned cephalograms digitized with a customized analysis program. The reproducibility of the measurements obtained by this method needed to be proven prior to using this method to measure treatment and growth changes in further investigations.

2.2 Materials and Methods

The custom cephalometric analysis was designed to provide information to conveniently allow comparison of the horizontal and vertical movements of landmarks of interest over time. The custom computer program measured cephalometric distances and angles according to a constructed grid. The grid was patterned after the style used by Mamandras and Allen (1990) with the horizontal reference at eight degrees from Sella - Nasion, approximating Frankfort horizontal. The vertical reference was a perpendicular line through Sella. See Figures 2.1 and 2.2. This provides a convenient method for measuring the anteroposterior as well as the vertical location of the landmarks with x,y coordinates. See Tables 2.1 and 2.2 for descriptions of the landmarks and linear measurements. See Table 2.3 for the definitions of angular measurements.

Table 2.1 Cephalometric Landmark Identification Definitions

Landmark	Identification Parameters
Sella (S)	The center of sella turcica
Nasion (N)	The suture between the frontal and nasal bones at the most posterior point on the curvature of the bridge of the nose
anterior nasal spine (ANS)	The anterior point of the maxilla
posterior nasal spine (PNS)	The posterior point of the maxilla
A-point (A)	The most posterior point on the curvature of the anterior maxilla
B-point (B)	The most posterior point on the curvature of the anterior mandible
Pogonion (Pg)	The most anterior point on the curvature of the bony chin
Gnathion (Gn)	The point bisecting the curvature at the anterior mandibular symphysis
Menton (Me)	The most inferior point at the mandibular symphysis
Gonion (Go)	The point bisecting the curvature of the angle of the mandible
Orbitale (O)	The average of the lowest point of each orbit
Porion (P)	The average of the highest point on each anatomic external auditory meatus
Mx 1	Maxillary incisor cusp tip
Md 1	Mandibular incisor cusp tip
Mx 6	Maxillary first permanent molar furcation point
Md 6	Mandibular first permanent molar furcation point

Table 2.2 Distances Definitions for Landmark Distances and Calculated Measurements

Measurement	Definition
PNS_Y	vertical distance between PNS and the constructed x-axis
PNS_X	horizontal distance between PNS and the constructed y-axis
ANS_Y	vertical distance between ANS and the constructed x-axis
ANS_X	horizontal distance between ANS and the constructed y-axis
A point_Y	vertical distance between A point and the constructed x-axis
A point_X	horizontal distance between A point and the constructed y-axis

B point_Y	vertical distance between B point and the constructed x-axis
B point_X	horizontal distance between B point and the constructed y-axis
Pg_Y	vertical distance between Pg and the constructed x-axis
Pg_X	horizontal distance between Pg and the constructed y-axis
Gn_Y	vertical distance between Gn and the constructed x-axis
Gn_X	horizontal distance between Gn and the constructed y-axis
Me_Y	vertical distance between Me and the constructed x-axis
Me_X	horizontal distance between Me and the constructed y-axis
O_Y	vertical distance between O and the constructed x-axis
O_X	horizontal distance between O and the constructed y-axis
Po_Y	vertical distance between Po and the constructed x-axis
Po_X	horizontal distance between Po and the constructed y-axis
Mx 1_Y	vertical distance between Mx 1 and the constructed x-axis
Mx 1_X	horizontal distance between Mx 1 and the constructed y-axis
Md 1_Y	vertical distance between Md 1 and the constructed x-axis
Md 1_X	horizontal distance between Md 1 and the constructed y-axis
Mx 6_Y	vertical distance between Mx 6 and the constructed x-axis
Mx 6_X	horizontal distance between Mx 6 and the constructed y-axis
Md 6_Y	vertical distance between Md 6 and the constructed x-axis
Md 6_X	horizontal distance between Md 6 and the constructed y-axis
PFH : AFH	The ratio of the distance from Sella to Gonion to the distance from Nasion to Menton
Overbite	The vertical difference between the mandibular incisor cusp tip and the maxillary incisor cusp tip on the reference grid

Overjet	The horizontal distance between the maxillary and mandibular incisor cusp tips on the reference grid
Lower Face Height (LFH)	The vertical distance on the reference grid between ANS and Menton

Figure 2.1 Distance Measurements

1) Lower face height 2) Overbite 3) Overjet

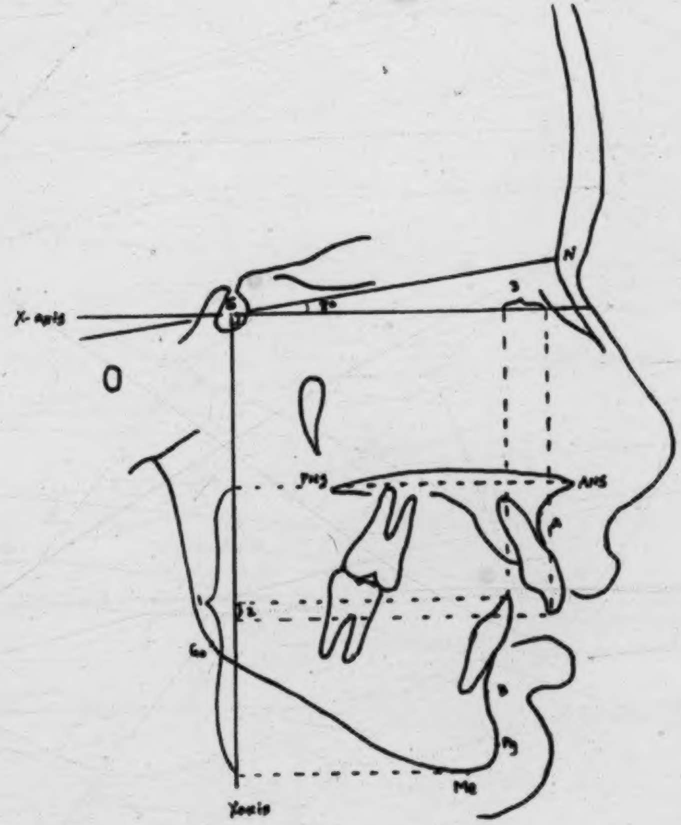
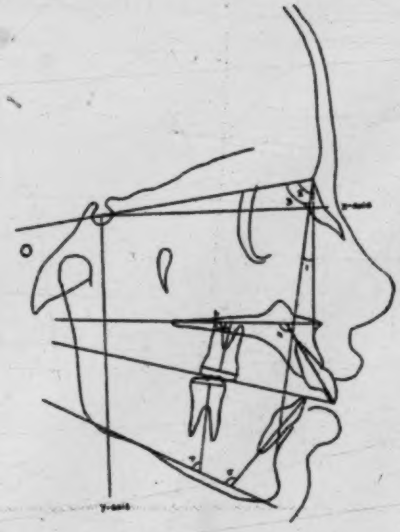

X-axis
S
7°
3
N
O
PNS
ANS
A
1
2
Go
B
Pg
Me
Yaxis

Table 2.3 Angular Measurement Definitions

Measurement	Definition
Mx 1 to Mx Pl	The angle of the maxillary central incisor to the maxillary plane
Mx 6 to Mx Pl	The angle of the maxillary first molar to the maxillary plane
Md 1 to Md Pl	The angle of the mandibular central incisor to the mandibular plane
Md 6 to Md Pl	The angle of the mandibular first molar to the mandibular plane
Occlusal Plane	The best fit of a line through the premolar and molar teeth to the horizontal axis of the reference grid.
Palatal Plane	The line between ANS and PNS to the horizontal axis of the reference grid
Mandibular Plane	The line between the points menton and gonion to the horizontal axis of the reference grid.
Y-axis	The angle between Sella-Nasion line and Sella-Gnathion

Figure 2.2 Angular Measurements



1) ANB 2) SNA 3)SNB
4) maxillary incisor to palatal plane
5) mandibular incisor to mandibular plane
6) maxillary molar to maxillary plane
7) mandibular molar to mandibular plane

Prior to use in this study the cephalometric program was checked to insure that the measurements it was recording were calculated correctly. Once the program had been checked for accuracy, the values generated by the program agreed with the values generated by hand tracing and measuring within the error of hand measurements.

Five cephalograms were randomly selected by lottery from the treatment groups for inclusion in this pilot study. The cephalograms had previously been scanned into the computer for digitization on an HP laserjet 600 scanner. The radiographs were digitized five separate times and the custom cephalometric analysis program computed the distance and angular measurements as needed for the study. The digitizations were performed with a minimum of twenty-four hours between to ensure that each trial was as independent as possible.

The data was subject to statistical analysis to determine the standard error of the measurements and reliability. The standard error was computed to provide a estimate of the numerical error that can be expected with each measurement. The reliability is an assessment of the accuracy of the method by comparing the error within repetitions on a single subject versus the variability across subjects.

It should be noted that the error analysis performed here includes both the landmark identification error and the measurement error associated with each of the measurements.

2.3 Results

The measurement tool investigated yielded consistent measurements. It can be seen that generally the mean measurements of standard deviation for each variable in the distance measurements fall within 1.0mm and the angles within 1 degree. See Table 2.4. The main exception to this being for orbitale and porion for the distance measurements and the tooth angulations in the angular measurements. The maximum error estimates are given by the upper boundary of the 95% confidence interval for the mean. This value is an indication of the maximum error that is likely to be associated with each measurement. These values also all fell within the 1mm or 1degree range with the same exceptions noted above. In addition PNS in the horizontal dimension, the mandibular molar furcation point in the vertical dimension and the occlusal plane showed maximum error estimates just over 1mm or 1degree.

Table 2.4: Mean Errors and Maximum Error in Distance and Angular Measurements

Landmark	Minimum	Maximum	Mean Error	Std. Error	Maximum Error
					95% CI for the mean error upper limit
PNS_X (mm)	0.4779	1.1638	0.87064	0.127769	1.2254
PNS_Y (mm)	0.2416	0.4558	0.33798	0.034242	0.4331
ANS_X (mm)	0.2758	0.6425	0.44828	0.06858	0.6387
ANS_Y (mm)	0.1982	0.4744	0.32678	0.058468	0.4891
A_X (mm)	0.05595	0.3276	0.25435	0.052381	0.3998
A_Y (mm)	0.222	0.6549	0.43816	0.092211	0.6942
B_X (mm)	0.2807	0.6476	0.42492	0.063459	0.6011
B_Y (mm)	0.2268	0.6048	0.43852	0.071512	0.6371
MX1_X (mm)	0.3313	1.2731	0.54198	0.183201	0.5131
MX1_Y (mm)	0.1396	0.6901	0.40524	0.105083	0.697
MD1_X (mm)	0.175	0.4953	0.36876	0.055001	0.5215
MD1_Y (mm)	0.1339	0.5219	0.34112	0.068405	0.531
MX6_X (mm)	0.1977	0.5745	0.3739	0.062234	0.5467
MX6_Y (mm)	0.1756	0.5257	0.31096	0.058609	0.4736
MD6_X (mm)	0.369	0.8231	0.57154	0.075133	0.7801
MD6_Y (mm)	0.09311	1.3141	0.490602	0.212654	1.081
PG_X (mm)	0.3223	0.6899	0.48344	0.063373	0.6594
PG_Y (mm)	0.2353	0.7357	0.4689	0.08589	0.7074
GN_X (mm)	0.3289	0.7277	0.50746	0.082668	0.737
GN_Y (mm)	0.233	0.5499	0.38022	0.052603	0.5263
ME_X (mm)	0.4103	0.7131	0.49526	0.055528	0.6494
ME_Y (mm)	0.1982	0.4303	0.29342	0.040598	0.4061
LFH (mm)	0.1171	0.2681	0.2135	0.025806	0.2851
OB (mm)	0.0503	0.2774	0.15203	0.048247	0.286

OJ (mm)	0.06465	0.9448	0.29793	0.163195	0.751
O_X (mm)	0.3415	2.8237	1.65726	0.499421	3.0439
O_Y (mm)	0.3479	0.7781	0.55726	0.072667	0.759
PO_X (mm)	0.5108	2.273	1.15206	0.314397	2.025
PO_Y (mm)	0.5457	2.1866	1.30032	0.325281	2.2034
ANB (degrees)	0.1057	0.4991	0.2242	0.071998	0.4241
Mx1 to Mx Pl (degrees)	0.3784	2.43	1.00114	0.371384	2.0323
Md1 to Md Pl (degrees)	0.8189	1.573	1.19426	0.138671	1.5793
Mx6 to Mx Pl (degrees)	1.2536	2.3384	1.49906	0.210553	2.0837
Md6 to Md Pl (degrees)	0.5047	2.4995	1.19052	0.387759	2.2671
SNA (degrees)	0.2597	0.6889	0.46312	0.069406	0.6558
SNB (degrees)	0.1683	0.5104	0.35048	0.069304	0.5429
Palatal plane (degrees)	0.1954	0.6536	0.39528	0.08701	0.6369
Occlusal plane (degrees)	0.3364	1.8852	0.99976	0.255229	1.7084
Mandibular plane (degrees)	0.271	0.4816	0.37866	0.043503	0.4994
Y-axis (degrees)	0.1056	0.4733	0.30066	0.065545	0.482642
PFH:AFH	0.004472	0.005477	0.004874	0.000246	0.005557

A reliability analysis was performed. The values for alpha were all 0.99 or better for the distances with the exception of porion, orbitale and PNS in the anteroposterior dimension ie. X values. See Table 2.5.

Table 2.5: Reliability Analysis for Distance Measurements

Variable	Alpha
PNS_X	0.9866
PNS_Y	0.9957
ANS_X	0.9980
ANS_Y	0.9974
A_X	0.9994
A_Y	0.9944
B_X	0.9980
B_Y	0.9968
MX1_X	0.9946
MX1_Y	0.9944
MD1_X	0.9990
MD1_Y	0.9974
MX6_X	0.9983
MX6_Y	0.9973
MD6_X	0.9943
MD6_Y	0.9915
PG_X	0.9964
PG_Y	0.9964
GN_X	0.9954
GN_Y	0.9973
ME_X	0.9960
ME_Y	0.9986
LFH	0.9987
OB	0.9991
OJ	0.9960
PO_X	0.8256
PO_Y	0.9523
OR_X	0.9270
OR_Y	0.9835
PFH:AFH	0.9890

Table 2.6 The Reliability of Angular Measurements

Variable	Alpha
ANB	0.9888
MX1 to Mx Pl	0.9850
MD1 to Md Pl	0.9991
MX6 to Mx Pl	0.9908
MD6 to Md Pl	0.9891
SNA	0.9970
SNB	0.9968
PALATAL	0.9961
OCCLUSAL	0.9839
MANDIBULAR	0.9868
Y-AXIS	0.9834

The reliability analysis for the angles shows good consistency with the error analysis by the mean of the standard deviations.(Table 2.6) The reliabilities for the lower molar, the maxillary incisor and the occlusal plane again are slightly below 0.99 as are ANB angle and the mandibular plane angle. The values are still very good with none below 0.98.

2.4 Discussion

The error analysis in this pilot study demonstrates that the scanned radiographs that were digitized and measured with the custom cephalometric analysis program used for this study yield acceptable accuracy for use in research.

The finding that porion and orbitale were not as reliable as the other landmarks present is not surprising and indeed agrees with the findings of other researchers. Jacobson (1990) found these two landmarks particularly subject to between investigator identification error. Baumrind and Frantz (1971) similarly found that orbitale is subject to higher error in location than many other cephalometric landmarks. They used a machine porion which significantly improved the reliability of the identification for this point. The same factors that make a landmark subject to high inter-investigator variability may also increase the error found with a single investigator performing repeated measures. For these points in particular, anatomy often limits the visibility of the landmark and an estimate of the expected position is chosen. Orbitale is often indistinct due to overexposure in this portion of the face and porion is subject to superimposition of the petrous ridge and sometimes the mastoid air cells.

The anatomy surrounding some other specific landmarks is also influential on the investigator's ability to reproducibly identify the same point. In the age group used for this study the maxillary second molars were often unerupted, especially on the time one films. This tooth in many individuals will be superimposed on the lateral cephalogram over PNS. This is likely to be responsible for the increased error associated with the measurements for this landmark.

The obscuring effect of superimposition of bilateral structures is particularly increased in the area of the dentition. The tooth angulation measures demonstrate a slightly higher variability. It is likely that a large part of the error seen in the angulation measurements of the incisor teeth again relates to superimposition problems. The age of the patients in the sample is such that, at time one the maxillary and sometimes the mandibular cuspids are unerupted and superimposed over the roots of their respective incisors. This leads to estimation of the position of the root tip to determine the angular measurement and the error is increased. Baumrind and Frantz (1971) also found an increased variability in this measurement in their investigation between operators. They state that the estimate required in locating such obscured points depends on the individual operators perception of dental anatomy and experience with this type of interpretive estimation from radiographs. The molar angulation variability may occur because it is difficult to identify enough landmarks on a tooth that are not obscured by superimposition of bilateral or adjacent teeth, to compute an angulation. The greater error associated with the angular measurements of the teeth will have to be taken into account with any future use of these measures.

Most of the landmarks demonstrate excellent reproducibility for the distance measurements with mean errors less than 0.5mm. Four points were slightly greater but still less than 1.0mm for estimated error. Orbitale and porion were included in this study to investigate the possibility of using Frankfort Horizontal as a reference line for another study. Orbitale and porion both show mean errors of greater than 1.0mm in at least one dimension. The level of error associated with these landmarks indicates that the increase in variability introduced by using Frankfort Horizontal as a reference line would be significant.

It is important to consider that within the error estimates of all of the landmark points measured in this investigation is the error associated with the identification of the landmarks for the reference lines construction. The reference lines are constructed from the Sella-Nasion line as discussed in the methods. The error involved with identification of these two landmarks must be quite small as any differences here would increase the variability of all points measured in the study.

The measurement tools tested in this pilot study are appropriate for use in research measuring lateral cephalometric radiographs.

2.5 References

Baumrind, S. & Frantz, R. C. (1971). The Reliability of Head Film Measurements 1. Landmark Identification. *American Journal of Orthodontics*, 60 (2), 111-127.

Jacobson, A. (1990). Planning for Orthognathic Surgery-Art or Science? *The International Journal of Adult Orthodontics and Orthognathic Surgery*, 5 (4), 217-224.

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Chapter 3

Pilot Study for Mandibular Superimposition

3.1 Introduction

Superimposition of tracings of lateral cephalometric radiographs has become an indispensable tool in the evaluation of growth and treatment changes on lateral cephalometric radiographs. The partial superimposition of single jaws allows much improved visualization of the dental changes occurring within this localized area. This is vital to understanding the complexity of the multiple areas of modification that occur in the growing face. The influence of one changing area upon another compounds as one considers the areas of the face from the cranial base down vertically to the mandible. Therefore it is most critical to consider the regional superimposition of the mandible as the effects of treatment and/or growth have interplayed all the way down the face. The interpretation of tooth movements here will be affected by all of the other changes and can only clearly be seen with localized superimposition.

The most accurate method of mandibular superimposition has been controversial. Springgate and Jones (1998)investigated some recommended methods of superimposition. They used subjects with implants to check the validity of their methods. They concluded that the anatomic superimposition on the internal architecture at the symphysis and the inner cortical structure of the lower border of the symphysis with orientation along the mandibular canal and the inferior contour of the third molar crypt provided the results closest to those obtained in implant superimposition. This was the method adopted for this pilot study. The purpose of this study is to investigate the error that occurs within the act of superimposition tracing for the specific investigator.

3.2 Methods

The vertical and horizontal movements of the landmarks was determined from coordinates measured by the grid constructed on the time one radiograph. See Figure 3.1 and Table 3.1 for description and definition of the measurements Similarly the angular changes for the teeth were measured with respect to the x-axis of the reference grid. The grid is designed with the x-axis at 8 degrees down from the Sella-Nasion line, approximating Frankfort Horizontal. This design was as used by Mamandras and Allen(1990).

Figure 3.1 Mandibular Superimposition

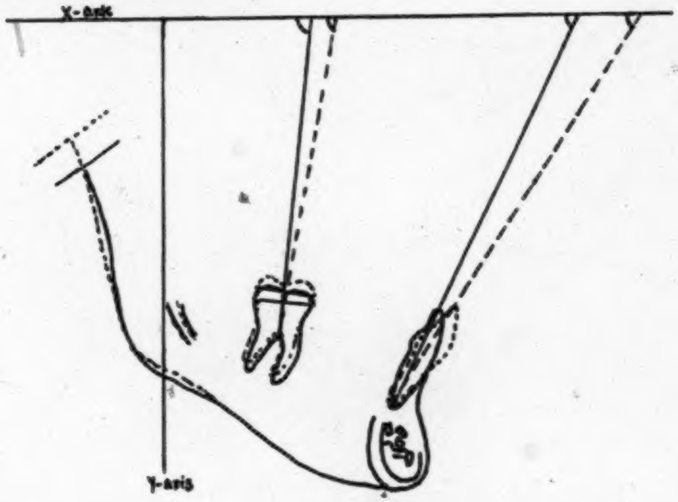

Table 3.1 Superimposition Measurement Definitions

Measurement	Definition
Incisor X	The horizontal distance of the mandibular incisor cusp tip from the vertical reference axis
Incisor Y	The vertical distance of the mandibular incisor cusp tip from the horizontal reference axis
Molar X	The horizontal distance of the mandibular first molar furcation point from the vertical reference axis
Molar Y	The vertical distance of the mandibular first molar furcation point from the horizontal reference axis
Gonion X	The horizontal distance of gonion to the vertical reference axis
Gonion Y	The vertical distance of gonion to the horizontal reference axis
Incisor Angle	The angle of the mandibular incisor to the horizontal axis of the reference grid
Molar Angle	The angle of the mandibular molar to the horizontal axis of the reference grid

Five cases were randomly selected by lottery to participate in the pilot study. These cases had the superimposition tracings repeated five times each. The repeats were performed with a minimum of twenty-four hours between to diminish the influence of the repeated nature of the investigation. The tracings were then digitized and the custom cephalometric analysis measured the distances and angles of interest.

The data was subject to statistical analysis to determine the standard error of the measurements and reliability. The standard error was computed to provide a estimate of the numerical error that can be expected with each measurement. The reliability is an assessment of the accuracy of the method by comparing the error within repetitions on a single subject versus the variability across subjects.

It should be noted that the error analysis performed here includes both the landmark identification error and the measurement error associated with each of the measurements.

3.3 Results

The superimposition pilot demonstrates that the distance measurements are highly reproducible but the angular measurements are very sensitive to small differences in the placement of the superimposition. See Tables 3.2 and 3.3.

Table 3.2: Descriptives for the Standard Deviation of Superimposition Measurements

Landmark	Minimum	Maximum	Mean Error	Std. Error	Maximum Error
					95% CI for the mean error upper limit
Incisor X (mm)	0.2331	0.6531	0.44232	0.087598	0.6855
Incisor Y (mm)	0.1264	0.7271	0.41344	0.12685	0.7656
Molar X (mm)	0.3343	0.8779	0.62626	0.086531	0.8665
Molar Y (mm)	0.4337	1.7752	0.89596	0.231805	1.5396
Gonion X (mm)	0.7214	1.0655	0.92622	0.065413	1.1078
Gonion Y (mm)	0.5773	1.0923	0.87442	0.091003	1.1271
Incisor Angle (degrees)	0.9663	3.5576	2.00952	0.47753	3.3354
Molar Angle (degrees)	1.0475	3.5342	2.13108	0.508009	3.5415

Table 3.3: Reliability Values for Superimposition Measurements

Landmark	Alpha Level
Incisor X	0.9874
Incisor Y	0.9862
Molar X	0.9074
Molar Y	0.7662
Gonion X	0.8705
Gonion Y	0.9528
Incisor Angle	0.9371
Molar Angle	0.8215

3.4 Discussion

The superimpositional error that occurs between investigators has been investigated by Baumrind, Miller and Molthen(1976). They found that between investigators superimposing on the mandibular border with registration at the inner cortical wall of the symphysis a rotational error of 1.23 degrees occurs which translated to 0.49mm to 0.80mm of error in the horizontal and vertical locations of tooth landmarks.

The reliability and error analysis for the superimposition are consistent with these findings indicating that there is significant variability that occurs in this activity. The angular measurements are shown to be more sensitive to the change in superimposition. This is not a surprising finding as any change in the axis of orientation will directly translate its full extent into the angular measurement. With the errors identified by this pilot study kept in mind the superimposition still provides a valuable insight into the tooth movements in the mandible.

3.5 References

Baumrind, S., Miller, D. & Molthen, R. (1976). The Reliability of Head Film Measurements 3. Tracing Superimposition. *American Journal of Orthodontics*, 70 (6), 617-644.

Mamandras, A. H. & Allen, L. P. (1990). Mandibular Response to the Bionator Appliance. *American Journal of Orthodontics and Dentofacial Orthopedics*, 97, 113-120.

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Chapter 4

Paper 1:

A Cephalometric Analysis of Twin Block Treatment of Overbite

4.1 Introduction

Control of the vertical dimension is frequently one of the most challenging aspects of correcting a malocclusion. There are relatively limited treatment alternatives to address this aspect of malocclusions especially the extremes of open bite and deep bite cases. The open bite cases also experience high rates of relapse. (Proffit, 1993) Severe Class II cases with excess vertical development are among the most difficult cases to treat as the tendency for the mandible to grow down and back can out pace the efforts to correct the anteroposterior discrepancy. In these extreme cases surgery may become the only method available to correct the problem. (McNamara, 1999) Growth modification with functional appliances is a common method for Class II treatment and has the potential for controlling patients' vertical development.

The Twin Block appliance is a currently popular functional appliance for correction of Class II patients and is also capable of concurrent transverse and vertical changes. This appliance, which was developed by Dr. William Clark (1988), is comprised of two separate removable appliances with inter-locking bite blocks. The flexibility provided by the bite blocks is the key to controlling the vertical dimension with this appliance.

Recent articles by Lund and Sandler(1998), Mills and McCulloch(1998), Illing, Morris and Lee(1998) and Toth and McNamara(1999) have all revealed the dental and skeletal effects of twin block appliances in the correction of Class II malocclusions. They have all also mentioned the ability of the twin block to create vertical changes and noted that these changes may also be impacting the results that are achieved. The forward component of the added eruption that occurs with the treatment to increase the vertical development has been speculated to contribute to the anteroposterior correction of the malocclusion. Lund and Sandler(1998)

This study investigates the vertical correction this appliance provides with the two different treatment protocols as compared to untreated control groups. The relationship between the correction of deep bite accomplished and the movements of the teeth and jaws is explored to determine which factors are most influential in this outcome.

4.2 Methods and Materials

Subjects

The patient pool in this retrospective study was a series of consecutively treated cases from the private practice of one of the authors. These patients were treated with this appliance based on presentation with significant Class II malocclusions. The patients had at least one molar full Class II and the patient showed improved facial balance when postured into a Class I relationship. The groups for analysis in this study were selected based on cutoff criteria for deep bite and open bite from this patient pool. The deep bite patients were identified as all patients with an initial overbite of greater than 4mm and open bite patients were all patients with an initial overbite of less than 1mm. The cases in these categories that were treated to open and close the bite respectively were used for the analysis in this study.

The treatment protocol for decreasing overbite and encouraging the vertical development involved regular adjustment of the appliance to reduce the bite block. The clinician trimmed the upper bite block selectively to permit eruption of the lower molar. See Figure 4.1. This added eruption is thought to contribute to increasing the vertical development of the face. In cases with anterior open bite where inhibition of vertical development was desired the bite blocks are not trimmed and remain fully covering all of the posterior teeth at the original height of about 5mm. This protocol is thought to inhibit the eruption of the posterior teeth and may affect the vertical skeletal development as well.

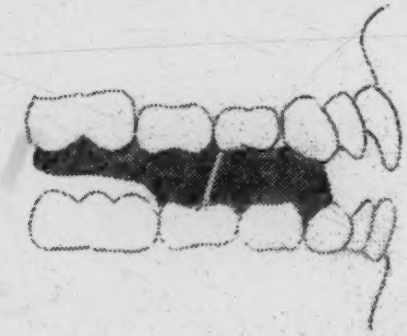


Figure 4.1: Treatment to increase the vertical dimension. The two interlocking bite blocks are constructed such that the mandible is maintained in a forward posture while the upper bite block is reduced to provide space for the lower molar to erupt.

The design of the Twin Block appliance used in this study was modified slightly from the original design by Clark(1988). The modifications included an acrylic labial bow added to the lower portion of the appliance to aid in retention and elastic hooks soldered to the delta clasps on the upper and lower appliance portions to allow wear of vertical elastics at night. The night time elastic wear was to aid in maintenance of the closed forward posture while sleeping. As advocated by Clark(1995), there were no labial bows on the maxillary appliance to minimize the lingual tipping forces applied to the upper incisors. The maxillary portion of the appliance also included an expansion screw which was used to correct the transverse relationships as the saggital correction progressed. The lower appliance did not include any expansion screws.

A control group was selected from the available records at the Bolton-Brush growth study. The control group was selected to correspond as closely as possible to the age, sex, and skeletal pattern, both sagittally and vertically, of the study group(Table 4.1). The same overbite criteria were applied to generate the groups for comparison. The deep control subjects had overbites greater than 4.0mm and the open control subjects had overbites less than 1.0mm at the time one cephalogram.

Table 4.1: Growth Indicators Used to Select Control Subjects

Vertical Skeletal Indicators	Class II Indicators	Other Variables
Y-axis	ANB	age
Mandibular Plane	Overjet	sex
PFH:AFH		
Palatal Plane		

Cephalometric Analysis

The radiographs were scanned into the computer using HP 600 Scanjet scanner and a custom software program was developed to provide the necessary measurements. The data was gathered from digitization of the lateral cephalograms before and after completion of phase I treatment for the treated groups. The control group had time 1 and time 2 lateral cephalograms digitized.

Landmarks of interest were selected to show the movements of the maxilla, mandible, incisors and molars both in terms of linear and angular changes (Table 4.2).

Table 4.2 Cephalometric Landmark Identification Definitions

Landmark	Identification Parameters
Sella (S)	The center of sella turcica
Nasion (N)	The suture between the frontal and nasal bones at the most posterior point on the curvature of the bridge of the nose
anterior nasal spine (ANS)	The anterior point of the Maxilla
posterior nasal spine (PNS)	The posterior point of the Maxilla
A-point (A)	The most posterior point on the curvature of the anterior Maxilla
B-point (B)	The most posterior point on the curvature of the anterior Mandible
Pogonion (Pg)	The most anterior point on the curvature of the bony chin
Gnathion (Gn)	The point bisecting the curvature at the anterior mandibular symphysis
Menton (Me)	The most inferior point at the mandibular symphysis
Gonion (Go)	The point bisecting the curvature of the angle of the Mandible
Mx 1	Maxillary incisor cusp tip
Md 1	Mandibular incisor cusp tip
Mx 6	Maxillary first permanent molar furcation point
Md 6	Mandibular first permanent molar furcation point

The custom computer program measured cephalometric distances and angles according to a constructed grid. The grid was as described by Mamandras and Allen (1990)with the horizontal reference at eight degrees from Sella - Nasion, approximating Frankfort horizontal. The vertical reference was a perpendicular line through Sella. This grid design provides a convenient method for measuring the anteroposterior changes as well as the vertical changes by comparing the difference in x,y coordinates for the landmarks on the time 1 and time 2 cephalograms. All points anterior and inferior to the reference axis are designated as positive values. The distance measurements are vertical and horizontal distances from the landmark to the reference axes. The changes at time two are calculated as the difference in the linear measurements - time two minus time one. Definitions for the linear distance for the landmarks and calculated distance measurements are found in Table 4.3.

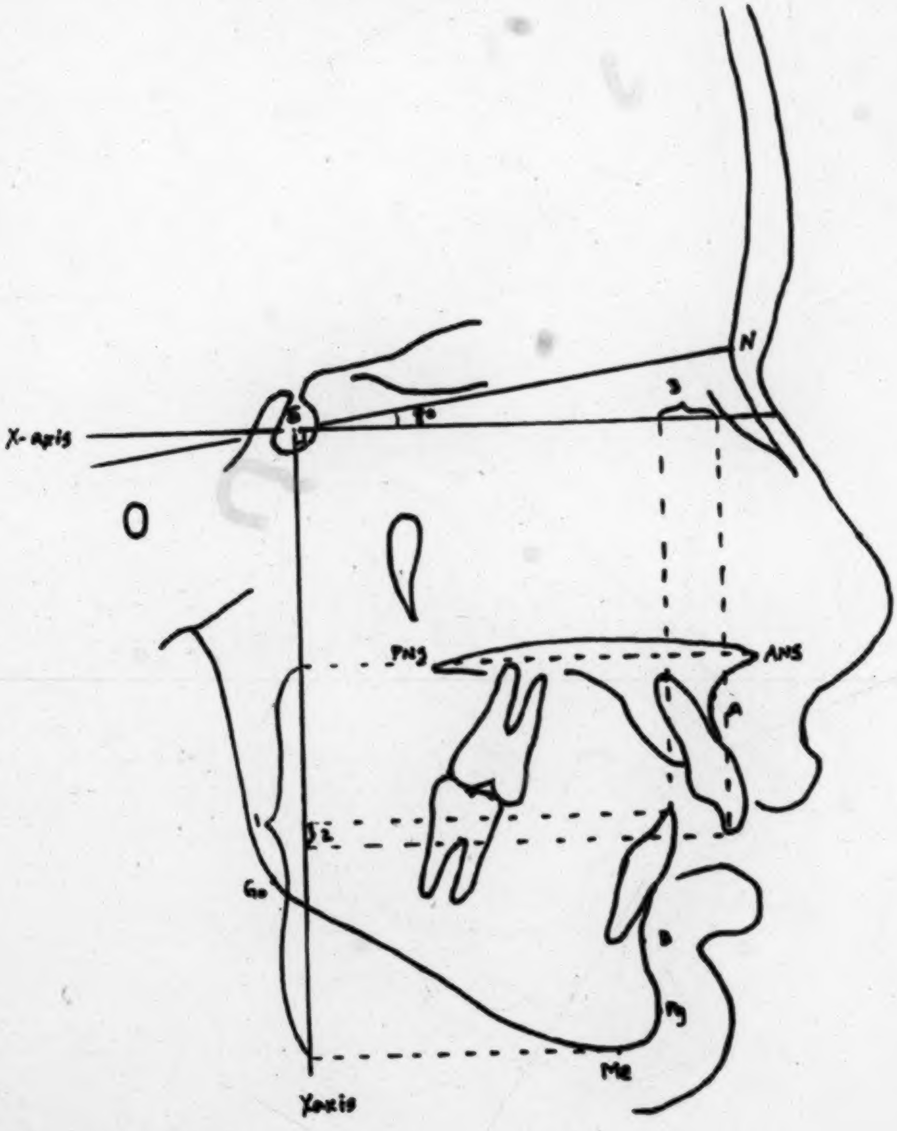
Table 4.3 Distances Definitions for Landmark Distances and Calculated Measurements

Measurement	Definition
PNS vertical	vertical distance between PNS and the constructed x-axis
PNS horizontal	horizontal distance between PNS and the constructed y-axis
ANS vertical	vertical distance between ANS and the constructed x-axis
ANS horizontal	horizontal distance between ANS and the constructed y-axis
A point vertical	vertical distance between A point and the constructed x-axis
A point horizontal	horizontal distance between A point and the constructed y-axis
B point vertical	vertical distance between B point and the constructed x-axis
B point horizontal	horizontal distance between B point and the constructed y-axis
Pg vertical	vertical distance between Pg and the constructed x-axis
Pg horizontal	horizontal distance between Pg and the constructed y-axis
Gn vertical	vertical distance between Gn and the constructed x-axis
Gn horizontal	horizontal distance between Gn and the constructed y-axis
Me vertical	vertical distance between Me and the constructed x-axis
Me horizontal	horizontal distance between Me and the constructed y-axis
Mx 1 vertical	vertical distance between Mx 1 and the constructed x-axis
Mx 1 horizontal	horizontal distance between Mx 1 and the constructed y-axis

Md 1 vertical	vertical distance between Md 1 and the constructed x-axis
Md 1 horizontal	horizontal distance between Md 1 and the constructed y-axis
Mx 6 vertical	vertical distance between Mx 6 and the constructed x-axis
Mx 6 horizontal	horizontal distance between Mx 6 and the constructed y-axis
Md 6 vertical	vertical distance between Md 6 and the constructed x-axis
Md 6 horizontal	horizontal distance between Md 6 and the constructed y-axis
PFH : AFH	The ratio of the distance from Sella to Gonion to the distance from Nasion to Menton
Overbite	The vertical difference between the mandibular incisor cusp tip and the maxillary incisor cusp tip on the reference grid
Overjet	The horizontal distance between the maxillary and mandibular incisor cusp tips on the reference grid
Lower Face Height (LFH)	The vertical distance on the reference grid between ANS and Menton

Figure 4.2: Distance Measurements

1) Lower face height 2) Overbite 3) Overjet


N
S
7°
X-axis
3
PNS
ANS
A
1
2
Go
B
Pg
Me
Y axis

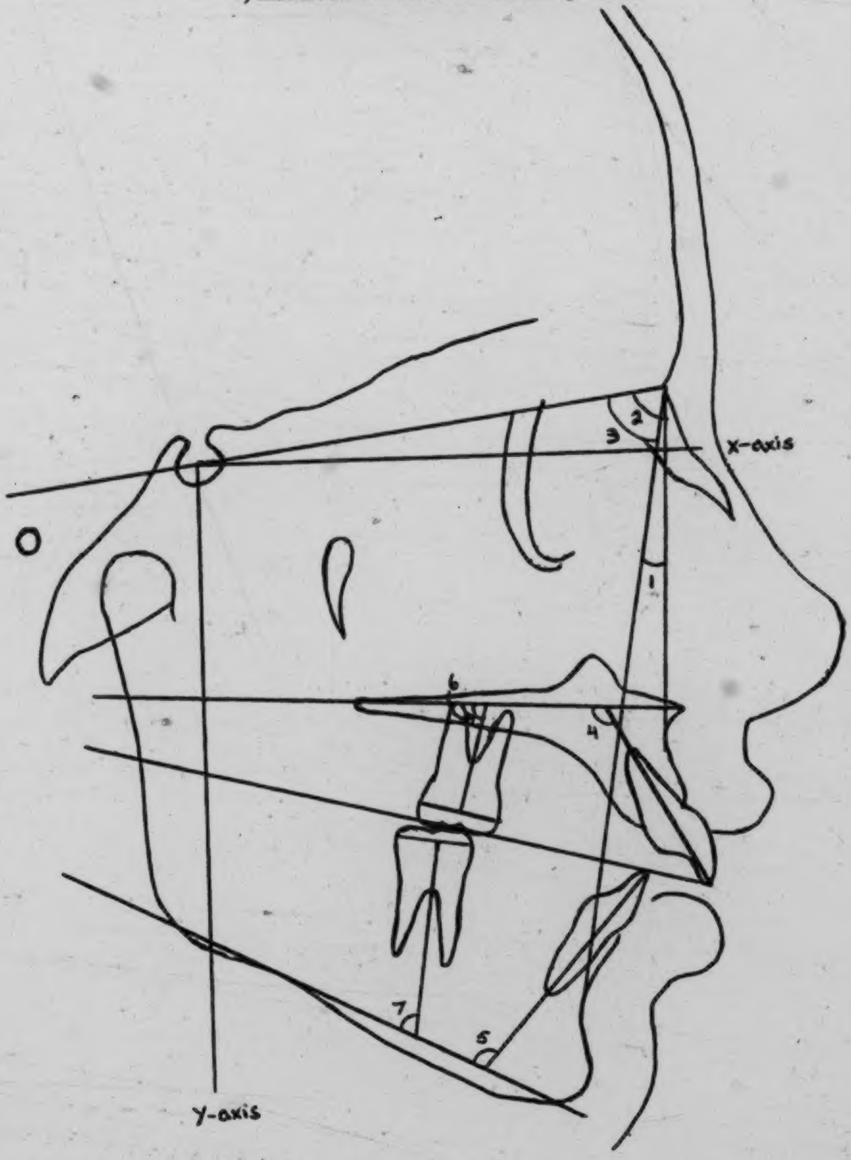
The custom cephalometric analysis program also recorded angular changes. Conventional angular measurements were used to investigate relational changes of the teeth and jaws. The molar angles were taken by construction of an axis line. The axis being defined as perpendicular to a line joining the mesial and distal heights of contour of the crown taken through the furcation point of the tooth. See Table 4.4 and Figure 4.3 for description of angular measurements.

Table 4.4 Angular Measurement Definitions

Measurement	Definition
Mx 1 to Mx Plane	The angle of the maxillary central incisor to the maxillary plane
Mx 6 to Mx Plane	The angle of the maxillary first molar to the maxillary plane
Md 1 to Md Plane	The angle of the mandibular central incisor to the mandibular plane
Md 6 to Md Plane	The angle of the mandibular first molar to the mandibular plane
Occlusal Plane	The best fit of a line through the premolar and molar teeth to the horizontal axis of the reference grid.
Palatal Plane	The line between ANS and PNS to the horizontal axis of the reference grid
Mandibular Plane	The line between the points menton and gonion to the horizontal axis of the reference grid.
Y-axis	The angle between Sella-Nasion line and Sella-Gnathion

Figure 4.3: Angular Measurements

1) ANB 2)SNA 3) SNB
4) maxillary incisor to palatal plane
5) mandibular incisor to mandibular plane
6) maxillary molar to maxillary plane
7) mandibular molar to mandibular plane



Superimposition of the mandible was performed to better visualize the tooth movements with respect to the jaw in this arch. See Figure 4.4 and Table 4.5 for the measurements. The cephalograms were partially traced with 0.5mm HB pencil on acetate tracing paper to allow superimposition of the mandible on anatomic structures. The internal anatomy at the symphysis and the mandibular canal were used to determine the orientation of the superimposition as this has been reported to be the most consistent with implant studies in approximating the true orientation. (Springate and Jones, 1998). The tracings were then scanned and digitized. The measurements were taken from the reference grid from the time one cephalogram which was included on the tracing.

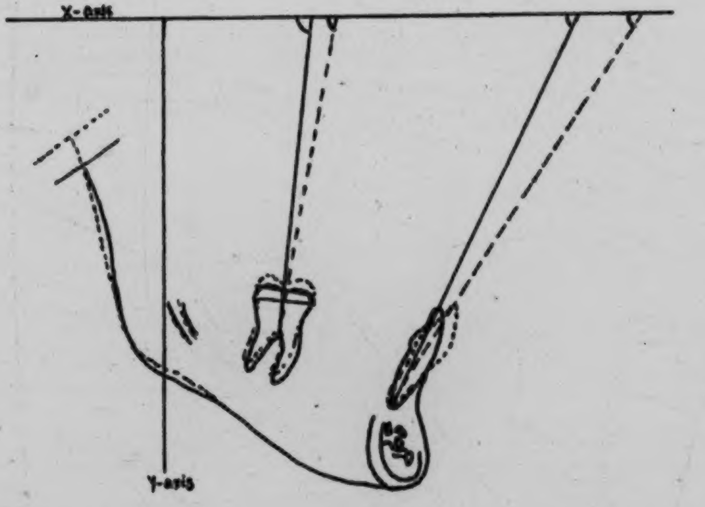


Figure 4.4: Mandibular Superimposition Measurements

Table 4.5 Superimposition Definitions

Measurement	Definition
Incisor X	The horizontal distance of the mandibular incisor cusp tip from the vertical reference axis
Incisor Y	The vertical distance of the mandibular incisor cusp tip from the horizontal reference axis
Molar X	The horizontal distance of the mandibular first molar furcation point from the vertical reference axis
Molar Y	The vertical distance of the mandibular first molar furcation point from the horizontal reference axis
Gonion X	The horizontal distance of gonion to the vertical reference
Gonion Y	The vertical distance of gonion to the horizontal reference
Incisor Angle	The angle of the mandibular incisor to the horizontal axis of the reference grid
Molar Angle	The angle of the mandibular molar to the horizontal axis of the reference grid

For both the tracings and radiographs digitized in this study the magnification was known and entered into the computer such that the measured values are corrected to actual anatomic size.

Pilot studies were performed to determine the reproducibility of the digitizing as well as the reproducibility of the superimposition tracings. The scanned and digitized cephalograms yielded reliability measurements of 0.98 or better for all of the landmarks used in this study. The mean error associated with the linear and angular measurements was less than 1.0 mm or 1.0 degrees for all measures except the tooth angulations which were less than 1.5 degrees. The superimposition tracing gave slightly higher error values with the distance measurements having a mean error of less than 1.0mm and the angular measurements having mean errors of approximately 2 degrees. The reliability for these measures was better than 0.82 for all measurements except the molar vertical which was 0.76. The action of superimposition tracing increased the error associated with these measurements but they are still valuable in clarifying the movements of the teeth within the lower jaw by removing the influence of the changes occurring elsewhere in the face.

The digitizations were repeated twice for each cephalogram and tracing and checked for accuracy. Where discrepancies of greater than 2mm or 2 degrees were found a third digitization was performed to determine the most accurate values. The duplicate measurements were then averaged to provide the data.

The groups were compared to their controls to determine pretreatment differences in the group composition, including the initial age, gender distribution and time interval between radiographs. T-tests were used to compare the pretreatment measurements of the variables. T-tests were used again to compare the treatment changes produced from time one to time two. The assumptions of normal distribution and equal standard deviations were investigated. The assumption of equality of standard deviation was not met and the t statistic was adjusted accordingly whereas the assumption of normality appeared to be correct. For the deep bite groups the information from the t-tests is important in the analysis of the regressions that follow. The deep group was further investigated with multiple linear regression analysis in order to identify which dental and skeletal factors were the most influential in the outcome of the change in overbite. A further multiple linear regression analysis was performed with the combined group of variables to identify the relative importance of the dental and skeletal factors. These regression analyses were produced with the age and treatment duration removed as these factors were found to be correlated with the change in overbite and the other variables of interest in the regression.

Marginal R-squared values were calculated for the variables to allow better interpretation of their role in the change in the overbite observed.

4.3 Results

Group Composition

There were 41 cases in the deep bite treatment group and 24 in the deep bite control. The open bite group was considerably smaller with 8 treated cases and 7 control. The following Tables 4.6 - 4.9 show the age, treatment duration and gender statistics for group compositions of the treatment versus the control for the open bite and deep bite groups. The deep groups compare very well for group composition. The open groups are much less than equivalent. They are significantly different for all of the group composition parameters.

Table 4.6 Open Bite Treatment and Control Group Composition

	Treatment group	Mean	Std. Deviation	Mean Difference	p-value (2-tailed)
Age at time 1 in months	*2	107.714	10.996	14.464	0.013
	**3	93.250	6.341		
Treatment duration(months)	2	11.571	2.573	-11.304	0.008
	3	22.875	8.741		

*2= open bite treatment **3 = control

Table 4.7 Open Bite Treatment and Control Group Composition for Gender

		Sex		Total
		male	female	
Treatment group	*2	2(29%)	5(71%)	7
	**3	5(63%)	3(38%)	8

*2= open bite treatment **3 = control

Table 4.8 Deep Bite Treatment and Control Group Composition

	Treatment group	Mean	Std. Deviation	Mean Difference	p-value (2-tailed)
Age at time 1 in months	*1	108.610	12.212	-1.640	0.597
	**3	110.250	11.877		
Treatment duration(months)	1	14.585	4.749	-2.581	0.205
	3	17.167	9.063		

* 1= deep bite treatment **3= control

Table 4.9 Deep Bite and Deep Bite Control Groups Gender Composition

		Sex		Total
		male	female	
Treatment group	*1	18(44%)	23(56%)	41
	**3	12(50%)	12(50%)	24

*1= deep bite treatment **3= control

Pretreatment Differences

T-tests were performed to investigate the pretreatment differences of all of the measurements used in this study. The significant variables are listed in the following Tables 4.10 - 4.13 for the complete tables see Appendix I.

The open group showed a more severe Class II relationship for the treatment group than the control. The groups for the open comparison were very small and many of the variables with clinically significant differences in the mean values did not reach statistical significance due to the relatively large standard deviations. The main pretreatment difference for the deep bite group is that the maxilla and maxillary dentition are positioned about 2mm lower in the face for the treatment group as compared to the control. The overjet and ANS horizontal also indicate a more severe Class II relationship for the treatment group.

Table 4.10 Dental Pretreatment T-tests Open Treatment Group Versus Control

Statistically Significant Variables Only

	Treatment Group	Mean	Std. Deviation	Mean Difference	p-value (2-tailed)
Vertical					
MX6 (mm)	*2	45.056	1.878	4.616	0.009
	**3	40.440	3.625		
Horizontal					
OVERJET (mm)	2	8.516	1.587	3.480	0.007
	3	5.037	2.510		

*2= open bite treatment **3= control

Table 4.11 Skeletal Pretreatment T-tests Open Treatment Group Versus Control

Statistically Significant Variables Only

	Treatment Group	Mean	Std. Deviation	Mean Difference	p-value (2-tailed)
Angular					
SNB (degrees)	*2	73.047	2.574	-3.793	0.011
	**3	76.841	2.316		

*2= open bite treatment **3= control

Table 4.12 Dental Pretreatment T-test Deep Treatment Group Versus Control

Statistically Significant Variables Only

	Treatment Group	Mean	Std. Deviation	Mean Difference	p-value (2-tailed)
Vertical					
MX1(mm)	*1	62.705	3.312	2.063	0.014
	**3	60.642	3.045		
MX6(mm)	1	44.015	2.941	2.280	0.002
	3	41.735	2.666		
MD6(mm)	1	61.492	3.255	1.837	0.026
	3	59.655	3.042		
OVERBITE (mm)	1	6.011	1.217	0.823	0.002
	3	5.188	0.862		
Horizontal					
OVERJET (mm)	1	6.804	2.356	1.873	0.001
	3	4.931	1.890		

*1= deep bite treatment **3= control

Table 4.13 Skeletal Pretreatment T-tests Deep Treatment Group Versus Control

Statistically Significant Variables Only

	Treatment Group	Mean	Std. Deviation	Mean Difference	p-value (2-tailed)
Vertical					
PNS (mm)	*1	37.143	1.978	1.880	0.001
	**3	35.263	2.191		
A (mm)	1	41.750	2.716	1.708	0.014
	3	40.041	2.567		
Horizontal					
ANS (mm)	1	66.397	4.427	2.300	0.047
	3	64.097	4.369		

*1= deep bite treatment **3= control

Post Treatment Results

The open bite group did not show any significant difference in the change in overbite with treatment. See Table 4.14. The mean values indicate that on average the control had more bite closing than the treated group. The difference was not statistically significant though with these small group sizes.

Table 4.14 Open bite Change in Overbite Compared to Control

	treatment group	N	Mean	Std. Deviation	Mean Difference	Sig. 2-tailed p-value
change in overbite (mm)	open treatment	7	-0.75286	1.222872	1.975476	0.074039
	control	8	-2.72833	2.4934		

There was found to be a significant difference between the change in overbite in the deep bite treatment group and the deep bite control group. See Table 4.15. This difference was significant even when corrected for pretreatment differences in overbite and controlled for age, gender, and treatment duration. The correction for these factors was performed with a regression analysis. The regression analysis used the information from the control group to create a model for the overbite at time 2 based on the overbite at time 1 and the gender, age, and treatment duration. This provided a model that was used to recalibrate the data from the treatment group. The recalibrated data was compared to the actual treatment group overbite at time 2 with a paired sample t-test to generate the corrected p-value. The details of this regression analysis correction can be found in Appendix II.

Table 4.15 Deep bite Change in Overbite Compared to Control

	treatment group	N	Mean	Std. Deviation	Mean Difference	Adjusted one tailed p-value
change in overbite (mm)	deep treatment	41	3.988049	1.657277	4.298604	0.000
	control	24	-0.31056	0.934523		

Time - one measurements were subtracted from the time two measurements to give the change occurring in that landmark. T-tests were performed on the measured changes in the variables over the treatment time. These tests identify variables that changed significantly as compared to the control and give the mean differences observed. The t-tests for the open bite groups are presented in Tables 4.16 and 4.17. The dental t-tests for the changes in the deep bite groups over the treatment period are found in Table 4.18 and the skeletal t-tests are found in Table 4.19.

Table 4.16 T-tests of Dental Measurement Changes over Treatment (Observation) Time for Open Bite Group

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	p-value
Vertical					
MX1 (mm)	*2	2.946	0.966	-1.017	^0.422
	**3	3.963	3.244		
MD1 (mm)	2	2.194	1.376	1.033	^0.195
	3	1.161	1.550		
MX6 (mm)	2	0.394	1.405	-2.885	^^0.004
	3	3.279	2.118		
MD6(mm)	2	3.229	1.056	-0.002	^0.998
	3	3.231	2.342		
OB (mm)	2	0.753	1.223	-1.975	^0.074
	3	2.728	2.493		
Horizontal					
MX1 (mm)	2	-2.233	1.993	-4.611	^^0.000
	3	2.378	1.632		
MD1 (mm)	2	3.825	1.225	1.301	^^0.048
	3	2.524	1.563		
MX6 (mm)	2	-0.901	1.354	-2.949	^^0.001
	3	2.048	1.417		
MD6(mm)	2	2.996	1.516	-0.349	^0.717
	3	3.344	2.114		
OJ (mm)	2	-6.056	2.489	-5.905	^^0.000
	3	-0.152	0.986		
Angular					
MX1 to MXPL (degrees)	2	-5.614	5.388	-4.990	^^0.057
	3	-0.623	6.024		
MD1 to MDPL (degrees)	2	1.946	3.364	2.842	^^0.095
	3	-0.896	4.563		
MX6 to MXPL (degrees)	2	-6.982	6.732	-9.380	^^0.017
	3	2.398	8.589		
MD6 to MDPL(degrees)	2	-2.592	6.087	2.231	^^0.311
	3	-4.823	10.605		
Occlusal Plane (degrees)	2	0.057	2.265	1.955	^0.194
	3	-1.898	3.223		
Superimposition					
Incisor X (mm)	2	1.303	0.757	0.650	^^0.098
	3	0.653	1.081		
Incisor Y (mm)	2	-0.108	0.760	-1.569	^0.019
	3	1.461	1.391		
Molar X (mm)	2	0.742	0.722	-0.305	^0.397
	3	1.047	0.607		
Molar Y (mm)	2	-0.015	0.986	-0.406	^^0.235
	3	0.391	1.127		

Incisor Angle (degrees)	2	-2.816	3.073	-2.422	^^0.135
	3	-0.394	4.921		
Molar Angle (degrees)	2	0.571	2.799	-0.914	^^0.284
	3	1.486	3.247		

*2= open bite treatment **3= control
^ two tailed p-value ^^ one tailed p-value

Table 4.17 T-tests for Skeletal Measurement Changes over Treatment (Observation) Time for Open Bite Group

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	p-value
Vertical					
PNS (mm)	*2	1.236	0.778	-0.460	^^0.231
	**3	1.695	1.486		
ANS (mm)	2	1.396	0.942	-0.324	^^0.369
	3	1.720	2.444		
A (mm)	2	1.855	1.341	-0.154	^^0.442
	3	2.009	2.545		
B (mm)	2	1.749	1.470	0.281	^0.764
	3	1.469	2.057		
PG (mm)	2	2.792	1.429	0.197	^0.848
	3	2.595	2.405		
GN (mm)	2	2.501	1.162	-0.287	^0.720
	3	2.788	1.910		
ME (mm)	2	2.121	1.017	-0.795	^0.328
	3	2.916	1.906		
LFH (mm)	2	0.721	0.452	-0.529	^^0.128
	3	1.250	1.137		
PFH:AFH	2	-0.009	0.011	-0.011	^0.168
	3	0.003	0.018		
Horizontal					
PNS mm)	2	0.348	1.787	0.492	^0.524
	3	-0.144	0.858		
ANS (mm)	2	-0.043	1.096	-1.313	^^0.035
	3	1.270	1.461		
A (mm)	2	-0.462	1.026	-1.354	^^0.012
	3	0.892	1.011		
B(mm)	2	3.061	2.064	1.155	^^0.105
	3	1.907	0.925		
PG (mm)	2	3.084	2.064	0.607	^^0.260
	3	2.476	1.317		
GN (mm)	2	3.119	2.113	0.609	^^0.257
	3	2.511	1.154		
ME (mm)	2	3.206	1.998	0.836	^^0.178
	3	2.370	1.165		
Angular					
ANB (degrees)	2	-2.849	1.516	-1.983	^^0.007
	3	-0.866	0.853		

SNA (degrees)	2	-0.953	1.051	-0.970	^^0.085
	3	0.018	1.512		
SNB (degrees)	2	1.897	1.268	1.194	^^0.036
	3	0.703	1.043		
Palatal Plane (degrees)	2	0.234	1.243	0.198	^^0.403
	3	0.036	1.780		
Mandibular Plane (degrees)	2	-0.567	1.136	-0.317	^^0.292
	3	-0.250	1.033		
Y-axis (degrees)	2	-0.851	1.279	-0.436	^^0.225
	3	-0.415	0.762		
Superimposition					
Gonion X (mm)	2	-0.611	3.073	1.756	^0.034
	3	-2.366	4.921		
Gonion Y (mm)	2	0.600	2.799	1.714	^0.091
	3	2.314	3.247		

*2= open bite treatment **3= control

^ two tailed p-value ^^ one tailed p-value

Table 4.18 T-tests of Dental Measurement Changes over Treatment (Observation) Time for Deep Bite Group

	Treatment Group	Mean	Std. Deviation	Mean Difference (treatment - control)	p-value
Vertical					
MX1 (mm)	*1	2.390	1.910	-0.373	^0.409
	**3	2.763	1.639		
MD1 (mm)	1	6.370	2.147	3.976	^^0.000
	3	2.394	1.780		
MX6 (mm)	1	0.852	1.433	-2.019	^0.000
	3	2.871	1.582		
MD6 (mm)	1	3.601	1.477	0.674	^0.145
	3	2.927	1.908		
OB (mm)	1	-3.988	1.657	-4.299	^^0.000
	3	0.311	0.935		
Horizontal					
MX1 (mm)	1	-0.450	2.894	-1.699	^^0.003
	3	1.249	1.886		
MD1 (mm)	1	4.444	2.650	3.218	^^0.000
	3	1.226	2.140		
MX6 (mm)	1	-0.083	1.648	-1.281	^^0.002
	3	1.198	1.675		
MD6 (mm)	1	4.309	2.629	2.617	^^0.000
	3	1.692	2.627		
OJ (mm)	1	-4.891	2.373	-4.900	^^0.000
	3	0.009	0.967		
Angular					
MX1 to MXPL (degrees)	1	-1.981	7.326	-1.421	^^0.143

	3	-0.560	3.227		
MD1 to MDPL (degrees)	1	4.588	4.174	4.265	^^0.000
	3	0.323	2.458		
MX6 to MXPL (degrees)	1	-8.283	5.887	-7.647	^^0.000
	3	1.384	4.977		
MD6 to MDPL (degrees)	1	-2.881	5.077	-2.266	^0.079
	3	-0.416	4.827		
Occlusal plane (degrees)	1	3.874	3.784	5.155	^^0.000
	3	-1.281	3.505		
Superimposition					
Incisor X (mm)	1	2.025	1.211	1.715	^^0.000
	3	0.310	0.860		
Incisor Y (mm)	1	-0.769	1.297	-1.680	^^0.000
	3	0.911	0.850		
Molar X (mm)	1	1.674	1.270	0.933	^^0.000
	3	0.741	0.861		
Molar Y (mm)	1	1.535	1.060	0.794	^^0.001
	3	0.742	0.768		
Incisor Angle (degrees)	1	-6.152	4.288	-5.068	^^0.000
	3	-1.084	2.772		
Molar Angle (degrees)	1	1.045	5.811	-1.219	^^0.132
	3	2.264	2.858		

*1= deep bite treatment **3= control

^ two tailed p-value ^^ one tailed p-value

Table 4.19 T-tests for Skeletal Measurement Changes over Treatment (Observation) Time for Deep Bite Group

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	p-value
Vertical					
PNS (mm)	*1	0.851	0.678	-0.557	^0.012
	**3	1.408	0.899		
ANS (mm)	1	1.336	1.638	-0.607	^0.233
	3	1.943	2.107		
A (mm)	1	1.205	1.888	-0.574	^0.259
	3	1.779	1.991		
B (mm)	1	5.432	2.223	2.681	^^0.000
	3	2.751	1.673		
PG (mm)	1	5.594	2.165	2.331	^^0.000
	3	3.262	2.043		
GN (mm)	1	5.422	1.907	2.153	^^0.000
	3	3.269	1.817		
ME (mm)	1	5.295	1.803	1.927	^^0.000
	3	3.368	1.655		

LFH (mm)	1	3.993	1.490	2.549	^^0.000
	3	1.444	1.145		
PFH:AFH	1	0.001	0.017	0.002	^0.593
	3	-0.001	0.016		
Horizontal					
PNS (mm)	1	0.266	1.665	-0.036	^^0.469
	3	0.303	1.906		
ANS (mm)	1	0.245	1.767	-0.837	^^0.059
	3	1.082	2.182		
A (mm)	1	0.042	1.396	-1.072	^^0.012
	3	1.114	1.948		
B (mm)	1	2.667	2.743	1.621	^^0.010
	3	1.046	2.535		
PG (mm)	1	2.480	3.151	1.120	^^0.070
	3	1.360	2.754		
GN (mm)	1	2.463	3.143	1.306	^^0.045
	3	1.157	2.819		
ME (mm)	1	2.569	3.164	1.463	^^0.031
	3	1.106	2.866		
Angular					
ANB (degrees)	1	-2.505	1.336	-2.320	^^0.000
	3	-0.185	1.436		
SNA (degrees)	1	-0.827	1.538	-0.502	^^0.219
	3	-0.325	2.897		
SNB (degrees)	1	1.704	1.737	1.656	^^0.001
	3	0.048	1.771		
Palatal Plane (degrees)	1	0.615	1.936	-0.012	^0.982
	3	0.626	2.121		
Mandibular Plane (degrees)	1	0.979	2.060	0.773	^^0.040
	3	0.206	1.417		
Y-axis (degrees)	1	0.253	1.960	-0.028	^0.946
	3	0.280	1.313		
Superimposition					
Gonion X (mm)	1	-1.933	1.499	-0.691	^0.037
	3	-1.242	1.097		
Gonion Y (mm)	1	1.767	1.866	0.991	^0.050
	3	0.777	1.947		

*1= deep bite treatment **3= control

^ two tailed p-value ^^ one tailed p-value

In order to explore the overbite reduction produced with the deep bite treatment, regressions were used to determine the contributions of the changes in the dental and skeletal variables to the change in overbite. The age and treatment duration factors had been identified as highly correlated with the change in overbite and the changes in the other variables examined were removed to clarify the regressions for dental, skeletal and combined dental and skeletal factors.

The dental regression model (Table 4.20) shows that the most important factors contributing to the change in overbite are the maxillary molar vertical position, the angulation of the lower incisor to the mandibular plane and the lower incisor position in the vertical and saggital dimensions. Despite the multiple other variables identified as statistically significant in this regression, they are probably not clinically significant given their low marginal R-squared values. The overall regression model is significant and gives an adjusted R-squared value of 49.9%.

Table 4.20 Regression Model for Dental Factors on the Change in Overbite

R - Squared 0.608 Adjusted R - Squared 0.494

Variable	Coefficient	S. E. of Coefficient	t-ratio	p-value	Marginal R-squared
constant	1.709	0.746	2.29	0.0029	
*Incisor Y	-0.758	0.242	-3.13	0.0038	17.6
MD1 to MDPL	0.267	0.087	3.08	0.0044	14.7
MX6 Y	0.445	0.164	2.71	0.0108	13.1
*Incisor X	-0.095	0.360	-2.49	0.0185	10.4
MD6 Y	-0.735	0.164	-4.49	0.0001	7.0
*Molar Y	0.857	0.278	3.08	0.0043	1.2
MD6 to MDPL	-0.155	0.050	-3.12	0.0039	0.8
MX1 X	0.278	0.102	2.73	0.0103	0.1
MD6 X	-0.368	0.120	-3.07	0.0044	≈0.0

*Superimposition measurements

The skeletal regression model is shown in Table 4.21. The most important skeletal factors responsible for the change in overbite are the lower face height, the pogonion vertical and gnathion vertical positions as well as the smaller contribution of the posterior nasal spine sagittally. As with the dental model other skeletal variables are statistically significant and contribute to the overall model despite an apparent lack of clinical significance. The model is successful in accounting for 64.2 % of the variation associated with the change in overbite and the adjusted R-squared is 57.9%.

Table 4.21 Model of Regression of Skeletal Factors on the Change in Overbite

R - Squared 0.642 Adjusted R - Squared 0.579

Variable	Coefficient	S. E. of Coefficient	t-ratio	p-value	Marginal R-squared
Constant	2.737	0.678	4.04	0.0003	
LFH	-1.043	0.178	-5.86	0.0001	34.8
PG Y	-1.335	0.372	-3.59	0.0010	13.4
GN Y	1.811	0.436	4.16	0.0002	9.0
PNS X	0.211	0.111	1.9	0.0656	4.2
PG X	1.715	0.587	2.92	0.0061	0.4
GN X	-1.976	0.607	-3.25	0.0026	0.4

The combined model includes both skeletal and dental variables in order to determine their relative significance on the outcome of overbite. See Table 4.22. The most important factors in this regression are the anterior mandibular points vertically - B point, pogonion, gnathion - the dental measurements including the maxillary molar vertical, the angulation of the lower incisor as well as its vertical position, and the combined measures that incorporate both skeletal and dental components such as the lower face height and mandibular molar vertical position. There are also some more modest contributors which include the mandibular incisor sagittal position (incorporating skeletal effects on this point) and the overjet. The overall model gives an R-squared of 0.92, explaining 92% of the variation in the change in overbite observed. The adjusted R squared is 86.1%.

Table 4.22 Combined Model of Dental and Skeletal Factors in Regression on the Change in Overbite

R - Squared 0.92 Adjusted R - Squared 0.861

Variable	Coefficient	S. E. of Coefficient	t-ratio	p-value	Marginal R-squared
Constant	1.308	0.448	2.92	0.0077	
LFH	-1.779	0.260	-6.86	0.0001	34.8
***Incisor Y**	-0.426	0.115	-3.72	0.0011	17.6
MD1 to MDPL	0.155	0.049	3.15	0.0044	14.7
PG Y	-2.173	0.347	-6.27	0.0001	13.4
MX6 Y	-0.252	0.147	-1.72	0.0996	13.1
B Y	0.285	0.108	2.64	0.0148	9.4
GN Y	3.131	0.535	5.85	0.0001	9.0
MD6 Y	-0.389	0.139	-2.8	0.0101	7.0
MD1 X	9.088	3.019	3.01	0.0062	3.1
OJ	9.303	3.026	3.07	0.0054	2.2
***Molar X**	-0.317	0.119	-2.66	0.0139	1.4
PNS Y	-1.267	0.277	-4.58	0.0001	0.5
PG X	1.906	0.486	3.92	0.0007	0.4
GN X	-1.324	0.415	-3.19	0.0040	0.4
MX1 X	-9.834	3.045	-3.23	0.0037	0.1
ME X	-0.636	0.176	-3.62	0.0015	0.1
MX1 to MXPL	0.204	0.056	3.63	0.0014	0.1

*Superimposition measurements

4.4 Discussion

The two treatment protocols investigated in this study are designed to adjust the vertical dimension while simultaneously correcting a Class II anteroposterior relationship. The protocol for the deep bite treatment with selective trimming of the bite block to allow the eruption of the mandibular molar produced a clinically and statistically significant decrease in the overbite for this group. The protocol for the open bite treatment with the maintenance of the bite blocks at the full height of 5mm throughout the treatment time did not produce any statistically significant change in the overbite.

A post hoc power analysis was performed for the open bite group. It showed that the power with these small samples and the high variation observed in the sample was only 27.6%.

Clinically speaking it is interesting to note that the control group experienced greater overbite closure by almost 2mm than the treatment group. This may be partially due to the young ages of the control group with a mean time one age of 7 $^3/_4$ years. It may be that some of the patients had incompletely erupted incisors at the time 1 cephalogram, whereas the treatment group had a mean time one age of almost 9 years. Although the open bite appliance did not close the overbite; it did not further reduce the overbite during the overjet correction. The control group was not well matched for this group. In addition to the younger time one age they were also observed for a longer time interval between radiographs and they did not match well in terms of gender. The findings in this group must be interpreted with these issues in mind.

The t-tests on the changes in the variables over the treatment time (observation time for the control group) demonstrate the specific change of each landmark. The landmarks chosen account for the movement of the teeth and jaws to provide a complete facial analysis. The examination of the t-tests for the open bite group further reinforces the suspected cause for the overbite changes noted between this treatment group and their control. It is observed that the treatment significantly restricts the eruption of the maxillary molar 2.9 mm and the lower molar moves down vertically 3.2mm, the same amount as the control. This is possible given the forward movement of the lower molar as the mandible is positioned forward. The control group experienced equal movement of the maxillary and mandibular molar maintaining the vertical relationship. The incisors in the control group erupted 1mm more than the treatment group to close the overbite approximately 2mm. It is interesting to observe the lack of vertical difference skeletally both statistically and in the magnitude of the actual measurements. At the same time statistically and clinically appreciable differences are noted in the horizontal skeletal landmarks. A point is restricted by a significant 1.4 mm and B point is forward (though not statistically significant) 1.1mm giving a 2.5mm differential change and statistically significant decrease in ANB of 2.0 degrees. This change in the ANB angle is equal in magnitude to the findings of Lund and Sandler (1998) although they found that there was very little or no restriction of maxillary growth and forward movement of B point was fully responsible for the correction. Mills and McCulloch (1998) and Toth and McNamara (1999) both also found ANB differences of approximately 2 degrees. While demonstrating significant mandibular movement in addition these investigators found some restriction of maxillary forward growth. There were no attempts in these studies to separate the patients based on the type of vertical treatment that they received and it would appear from the results in this investigation that the degree of contribution from the maxilla and mandible may be dependent on the type of vertical treatment delivered. This observation is made with caution however given the very small group sizes in this portion of the study. Regardless of the mechanism, the horizontal skeletal changes combined with the horizontal and rotational changes of the dentition create substantial overjet correction. The vertical relationship was maintained as the saggital changes were accomplished.

The deep bite treatment group had many significant changes over the treatment period as compared to their control group. The horizontal changes were similar to those of the open bite group while substantial vertical changes were noted as well. There was a 5.0mm overjet correction with dental and skeletal contribution. The skeletal horizontal changes remarkably similar to the open group with A point significantly restricted 1.1mm and B point significantly positioned forward 1.6 mm leading to a significant ANB decrease of 2.3 degrees. The vertical changes were also highly statistically significant and created overbite decrease of 4.3mm for the treatment group over the control group. The skeletal vertical changes were also significant in creating a 2.5mm increase in lower face height for the treatment group. The other large change apparent from the t-tests is the change in the occlusal plane which rotates downward by 5.2 degrees. These findings are generally in agreement with the findings from previous twin block studies by Lund and Sandler(1998), Mills and McCulloch(1998) and Toth and McNamara(1999) although not all of these studies measured all of the vertical indicators investigated here. These previous studies all mention an increased lower molar eruption and increased vertical development skeletally. The dramatic change in overbite that was produced for the deep group in this study was further investigated to determine which dental and skeletal factors were most influential in the correction. The regressions were corrected to remove the linear and quadratic effects of age and treatment duration. This was necessary due to the significant correlation that these factors had on the other variables included in the regression and on the outcome of the change in overbite. The removal of age and duration of treatment allowed the contributions of the other variables to be observed. This issue of correlation of variables is also important in interpreting the regressions. Variables were included in the regressions and due to their correlations with other included variables they appear as statistically significant despite the marginal R-squared values being very low.

The dental regression presented is the best model that could be derived including only the dental variables. It is clear that several dental variables are clinically significant to the changes in overbite. In particular the maxillary molar vertical position and the mandibular incisor vertical and horizontal position. The maxillary molar vertical position is somewhat paradoxical in its relationship to the change in overbite. There is a significant difference in the change in position of this tooth compared to the control group but the mean difference is opposite to what would be expected. It is expected that added vertical eruption would be desirable in the molar area for efficient overbite correction but the treatment group shows a mean restriction of vertical eruption of about 2mm for this tooth. This lack of eruption must be compensated for by the lower molar eruption. The mandibular molar vertical is also included in the dental regression. It appears as both the isolated dental change from the superimposition and as the change on the overall measurement which includes some skeletal contribution. Not surprisingly the measurement with the skeletal contribution has the more significant contribution to the overbite correction. Both measurements though are relatively small in terms of the mean difference from the control. The superimposition measurement shows an increased eruption of 0.8mm and the overall measurement shows a vertically lowered position for the treatment group of 0.7mm. Again the vertically lowered position on the overall measurements seems contradictory when taken in isolation but the fact that this tooth has also moved 2.6mm horizontally (from the overall measurements) such that it is on a lower portion of the occlusal plane is likely responsible for this outcome. The changes associated with the lower incisor are a little clearer to interpret. The lower incisor moves forward by 1.7mm compared to the control and is restrained in eruption vertically by 1.7mm. The vertical portion of these changes accounts for approximately half of the overbite correction. The horizontal portion is probably also related to angular change for this tooth. The mandibular incisor proclines 4-5 degrees more in the treatment group than the control. As the proclination occurs the horizontal position of the cusp tip is brought forward and the vertical position is lowered. This is the case if the center of rotation of the tooth is located at any point below the incisal edge of the tooth, which is likely given the appliance design. There is contact of the acrylic portion of the mandibular appliance about half way up the lingual surface of the incisor crowns. The angular measurements for the teeth in this study were subject to higher measurement errors with mean errors of approximately 1.1 degrees and maximum errors up to 2.2 degrees which should be taken into account when interpreting these results.

The skeletal regression gave fewer significant variables. The largest contributor is clearly the lower face height which increased by 2.5mm over the control group. This measurement includes a lot of the skeletal and dental changes that are occurring in individual landmarks. It is a summary measurement of the posterior skeletal and dental and anterior skeletal changes. This finding of increased lower face height agrees with Illing, Morris and Lee(1998) who found 2.7mm over nine months of treatment with the twin block appliance. Similarly Toth and McNamara(1999) found increase in lower face height of 3.0mm. Other variables that are important for the skeletal change are the vertical changes at pogonion and gnathion. These two points both move downward by 2mm in the treatment group as compared to the control. This measure of the downward displacement of the anterior mandible would account for approximately half of the 4.3mm overbite correction observed.

The combined regression is used to clarify the relative contribution of the various dental and skeletal factors. The summary measurement of the lower face height is again the most important single measurement with skeletal components of pogonion vertical and gnathion vertical. The dental measurements with most significant contribution approximately equal to that of the individual skeletal variables are the mandibular incisor vertical and the angulation of the mandibular incisor. Reappearing also is the maxillary molar vertical position. The difference in the position of this tooth between the treatment and control groups remains important to the overbite correction, likely due to its effect on the occlusal plane.

The t-tests are very instructive in examining the precise differences between the treatment and control groups. They demonstrate many significant but small changes in the movements of the teeth and jaws. The large significant differences occur in the measures such as the overbite, lower face height and occlusal plane where the dental and skeletal contributions are consolidated. The regressions are used to determine if there are particular identifiable dental or skeletal points that can be held largely responsible for the change in vertical dimension. It seems that there are a few clearly identifiable factors. The most critical factors appear to be the downward displacement of the anterior mandible and the combined dental movements including restriction of the maxillary molar vertical and proclination of the lower incisor, creating a steepening of the occlusal plane. It is also evident that there are many other skeletal and dental effects which are involved with the overbite correction and the simultaneous overjet correction that cannot be easily distinguished.

4.5 Appendix I

Pretreatment Dental T-tests Deep Bite Group Versus Deep Bite Control Group

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	Sig. (2-tailed)
Vertical					
MX1 (mm)	*1	-62.705	3.312	-2.063	0.014
	**3	-60.642	3.045		
MD1 (mm)	1	-56.698	2.904	-1.213	0.131
	3	-55.485	3.156		
MX6 (mm)	1	-44.015	2.941	-2.280	0.002
	3	-41.735	2.666		
MD6 (mm)	1	-61.492	3.255	-1.837	0.026
	3	-59.655	3.042		
OVERBITE (mm)	1	-6.011	1.217	-0.823	0.002
	3	-5.188	0.862		
Horizontal					
MX1 (mm)	1	65.387	5.592	1.486	0.312
	3	63.901	5.694		
MD1 (mm)	1	58.580	5.705	-0.416	0.767
	3	58.996	5.271		
MX6 (mm)	1	33.180	4.100	0.569	0.594
	3	32.612	4.138		
MD6 (mm)	1	24.905	4.665	-0.986	0.418
	3	25.891	4.724		
OVERJET (mm)	1	6.804	2.356	1.873	0.001
	3	4.931	1.890		
Angular					
MX1_MXPL (degrees)	1	110.914	7.964	0.153	0.924
	3	110.761	4.994		
MD1_MDPL (degrees)	1	96.121	6.779	-0.837	0.622
	3	96.958	6.443		
MX6_MXPL (degrees)	1	64.138	3.578	-1.374	0.272
	3	65.512	5.368		
MD6_MDPL (degrees)	1	78.615	4.358	-0.710	0.619
	3	79.325	6.082		
Occlusal plane (degrees)	1	12.679	5.246	-0.730	0.570
	3	13.409	4.803		

* 1 = deep bite treatment group **3 = deep bite control group

Pretreatment Skeletal T-tests Deep Bite Group Versus Deep Bite Control Group

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	Sig. (2-tailed)
Vertical					
PNS (mm)	*1	-37.143	1.978	-1.880	0.001
	**3	-35.263	2.191		
ANS (mm)	1	-37.475	2.790	-1.130	0.091
	3	-36.345	2.411		
A (mm)	1	-41.750	2.716	-1.708	0.014
	3	-40.041	2.567		
B (mm)	1	-73.391	3.709	-1.316	0.150
	3	-72.075	3.384		
PG (mm)	1	-85.363	4.261	-0.450	0.646
	3	-84.914	3.477		
GN (mm)	1	-88.672	4.024	-1.195	0.219
	3	-87.477	3.560		
ME (mm)	1	-90.610	4.012	-1.693	0.094
	3	-88.916	3.773		
LFH (mm)	1	-53.142	3.435	-0.496	0.534
	3	-52.647	2.848		
PFH_AFH	1	0.634	0.034	-0.005	0.595
	3	0.638	0.035		
Horizontal					
PNS (mm)	1	20.227	3.368	0.502	0.570
	3	19.725	3.440		
ANS (mm)	1	66.397	4.427	2.300	0.047
	3	64.097	4.369		
A (mm)	1	63.038	4.469	1.340	0.275
	3	61.698	4.864		
B (mm)	1	52.587	6.237	0.421	0.784
	3	52.167	5.756		
PG (mm)	1	52.382	7.069	1.067	0.539
	3	51.315	6.488		
GN (mm)	1	50.910	7.341	0.515	0.767
	3	50.395	6.337		
ME (mm)	1	48.109	7.337	-0.011	0.995
	3	48.120	6.304		
Angular					
ANB (degrees)	1	6.618	1.734	0.224	0.621
	3	6.394	1.756		
SNA (degrees)	1	80.548	3.417	-0.556	0.579
	3	81.104	4.108		
SNB (degrees)	1	73.931	3.234	-0.792	0.348
	3	74.724	3.266		
Palatal plane (degrees)	1	0.445	2.963	-1.014	0.222
	3	1.459	3.306		
Mandibular plane (degrees)	1	26.790	4.456	0.292	0.804

	3	26.498	4.612		
Y axis (degrees)	1	68.215	4.070	-0.001	0.999
	3	68.216	3.487		

* 1 = deep bite treatment group **3 = deep bite control group

Pretreatment Dental T-tests Open Bite Group Versus Open Bite Control

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	Sig. (2-tailed)
Vertical					
MX1 (mm)	*2	-60.464	3.913	-4.676	0.060
	**3	-55.788	4.848		
MD1 (mm)	2	-60.889	3.840	-4.232	0.067
	3	-56.657	4.376		
MX6 (mm)	2	-45.056	1.878	-4.616	0.009
	3	-40.440	3.625		
MD6 (mm)	2	-61.739	2.343	-3.366	0.057
	3	-58.374	3.746		
OVERBITE (mm)	2	0.426	1.426	-0.440	0.603
	3	0.866	1.763		
Horizontal					
MX1 (mm)	2	65.170	4.142	0.792	0.712
	3	64.378	3.967		
MD1 (mm)	2	56.654	4.831	-2.686	0.280
	3	59.339	4.293		
MX6 (mm)	2	32.015	4.006	-0.818	0.644
	3	32.833	2.261		
MD6 (mm)	2	24.490	4.332	-1.777	0.426
	3	26.267	3.988		
OVERJET (mm)	2	8.516	1.587	3.480	0.007
	3	5.037	2.510		
Angular					
MX1_MXPL (degrees)	2	111.876	5.744	-4.555	0.224
	3	116.431	7.982		
MD1_MDPL (degrees)	2	94.376	8.772	-6.084	0.220
	3	100.459	9.503		
MX6_MXPL (degrees)	2	63.518	5.110	-1.755	0.634
	3	65.273	8.563		
MD6_MDPL (degrees)	2	77.572	4.413	-1.371	0.662
	3	78.943	7.231		
Occlusal plane (degrees)	2	12.999	4.766	1.032	0.633
	3	11.968	3.039		

*2 = open bite treatment group **3 = open bite control group

Pretreatment Skeletal T-tests Open Bite Group Versus Open Bite Control Group

	Treatment	Mean	Std. Deviation	Mean Difference (treatment - control)	Sig. (2-tailed)
Vertical					
PNS (mm)	*2	-36.671	2.710	-1.672	0.207
	**3	-34.999	2.013		
ANS (mm)	2	-36.600	2.168	-2.278	0.123
	3	-34.323	3.124		
A (mm)	2	-40.477	2.173	-2.518	0.113
	3	-37.959	3.448		
B (mm)	2	-76.992	4.127	-4.830	0.097
	3	-72.162	6.176		
PG (mm)	2	-88.521	3.880	-4.772	0.116
	3	-83.749	6.759		
GN (mm)	2	-91.495	3.638	-5.202	0.074
	3	-86.293	6.394		
ME_Y (mm)	2	-93.604	3.671	-5.589	0.055
	3	-88.015	6.269		
LFH (mm)	2	-57.006	2.255	-3.314	0.155
	3	-53.692	5.567		
PFH_AFH	2	0.620	0.017	-0.014	0.302
	3	0.634	0.031		
Horizontal					
PNS (mm)	2	18.956	3.131	-1.185	0.424
	3	20.142	2.255		
ANS (mm)	2	65.375	3.698	1.966	0.284
	3	63.409	2.974		
A (mm)	2	62.300	4.676	1.019	0.631
	3	61.281	2.976		
B (mm)	2	50.309	4.696	-2.235	0.375
	3	52.544	4.694		
PG (mm)	2	50.134	5.183	-1.208	0.663
	3	51.342	5.292		
GN (mm)	2	48.991	5.421	-1.262	0.651
	3	50.253	5.074		
ME (mm)	2	46.696	5.728	-1.492	0.590
	3	48.188	4.510		
Angular					
ANB (degrees	2	7.132	2.362	0.186	0.856
	3	6.946	1.241		
SNA (degrees)	2	80.179	4.376	-3.606	0.084
	3	83.786	2.372		
SNB (degrees)	2	73.047	2.574	-3.793	0.011
	3	76.841	2.316		
Palatal plane (degrees)	2	-0.144	2.105	0.746	0.685
	3	-0.889	4.524		
Mandibular plane (degrees)	2	29.244	4.034	2.089	0.365

	3	27.155	4.591		
Y-axis (degrees)	2	69.829	3.391	2.105	0.275
	3	67.723	3.757		

*2 = open bite treatment group **3 = open bite control group

Appendix II

A regression analysis was used to correct for pretreatment difference in the overbite in order to generate the corrected p-value for the t-test. This was done by running a regression for the control group with the overbite at time two as the outcome variable and including the time one overbite, sex, age, treatment duration and age and treatment duration interaction as the independent variables.

Regression of Time Two Overbite for Control Group

			Unstandardized Coefficients		p-value
	Model		B	Std. Error	
	1	(Constant)	-6.572	6.656	0.337
		OVERBITE	0.631	0.273	0.033
		SEX	-0.066	0.418	0.876
		age at T1 in months	0.038	0.053	0.482
		treatment duration	0.264	0.311	0.406
		AGE_TXDR	-0.002	0.003	0.415

This generated a set of regression coefficients. The coefficients from the control were multiplied to their respective variables in the regression equation to generate a new variable the calculated overbite at time two. Then a paired t-test was performed on the actual overbite at time two for the treatment group and the calculated overbite at time two for the treatment group to give the corrected p-value. See the following table.

Paired T-test of the Deep Treatment Group Time - Two Overbite Versus the Calculated Time Two Overbite

	Mean	p-value (2-tailed)	Mean difference	Std. Deviation
OB2	-2.023	0.000	4.040	1.450
CAL_OB2	-6.063			0.770

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Chapter 5

Paper 2:

Investigation of Treatment Effects for Bite Opening and Non Bite Opening Twin Block Treatment Regimes

5.1 Introduction

The Twin Block appliance is a currently popular treatment choice for correction of Class II patients and is also designed to be capable of concurrent vertical changes. This appliance was developed by Dr. William Clark (1988). It is comprised of two separate removable appliances with inter-locking bite blocks which afford a convenient route for the correction of the vertical dimension.

Recent articles by Lund and Sandler(1998), Mills and McCulloch(1998), Illing, Morris and Lee(1998) and Toth and McNamara(1999) have all revealed the dental and skeletal effects of twin block appliances in the correction of Class II malocclusions. They have all also mentioned the ability of the twin block to create vertical changes and noted that these changes may be impacting the saggital correction that is achieved. The forward component of the added eruption that occurs with the selective trimming of the upper bite block has been speculated to contribute to the anteroposterior correction of the malocclusion. (Lund and Sandler, 1998) The twin block treatment groups in these previous studies were not evaluated based on their vertical treatment. All cases were included in examining the anteroposterior correction.

This investigation compares the treatment and growth changes observed with the two different treatment regimes for vertical dimension. The purpose of the comparison is to identify the factors that respond to produce the vertical changes and to identify any difference that may exist in the correction of the anteroposterior discrepancies between the two groups.

5.2 Methods and Materials

Subjects

The patient pool in this retrospective study was a series of consecutively treated cases from the private practice of one of the authors. These patients were treated with this appliance based on presentation with significant Class II malocclusions. The patients had at least one molar full Class II and the patient showed improved facial balance when postured into a Class I relationship. The groups for analysis in this study were selected based on the cut off criteria of an initial overbite greater than 4mm for the deep bite group and an initial overbite less than 2mm for the "preservation" of overbite group. The first group consisted of 41 cases treated to correct the deep bite. This group will be referred to as the deep group. The second group consisted of 12 cases treated to preserve or close the overbite. This will be referred to as the open group.

The design of the Twin Block appliance used in this study was modified slightly from the original design by Clark (1988). The modifications included an acrylic labial bow added to the lower portion of the appliance to aid in retention and elastic hooks soldered to the delta clasps on the upper and lower appliance portions to allow wear of vertical elastics at night. The night time elastic wear was to aid in maintenance of the closed forward posture while sleeping. As advocated by Clark(1995), there were no labial bows on the maxillary appliance to minimize the lingual tipping forces applied to the upper incisors. The maxillary portion of the appliance also included an expansion screw which was used to correct the transverse relationships as the saggital correction progressed. The lower appliance did not include any expansion screws. The bite blocks were fabricated to open the vertical by about 5mm.

In the deep cases where increased vertical development was desirable, the appliance was adjusted during treatment. Following the methods described by Clark(1995), the clinician trimmed the upper bite block selectively to permit differential eruption of the lower molar. This added eruption was expected to contribute to an increase in the vertical development of the face.

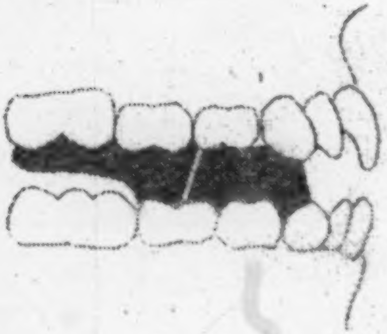


Figure 5.1: Treatment to increase the vertical dimension. **The two interlocking bite blocks are constructed such that the mandible is maintained in a forward posture while the upper bite block is reduced to provide space for the lower molar to erupt.**

In the open cases the bite blocks were not trimmed and remained fully covering all of the posterior teeth. The full coverage of the occlusal surface of these teeth was expected to maintain or inhibit their vertical eruption. It may be that some inhibition of vertical skeletal development may have occurred as well. (Iscan and Sarisoy, 1997)

Analysis

The pretreatment and post treatment lateral cephalograms were analyzed to provide the data for comparison of the treatment and growth effects. The lateral cephalograms were all taken on the same machine with an anode to midsubject distance of 5.0 feet(152.4cm).

There was an 11% enlargement factor on the films which was accounted for in the cephalometric analysis program.

All lateral cephalograms were scanned with an HP 600 Scanjet scanner and the scanned images were digitized using a custom cephalometric analysis. Landmarks of interest (Table 5.1) were selected to show the movements of the maxilla, mandible, incisors and molars in terms of linear and angular changes.

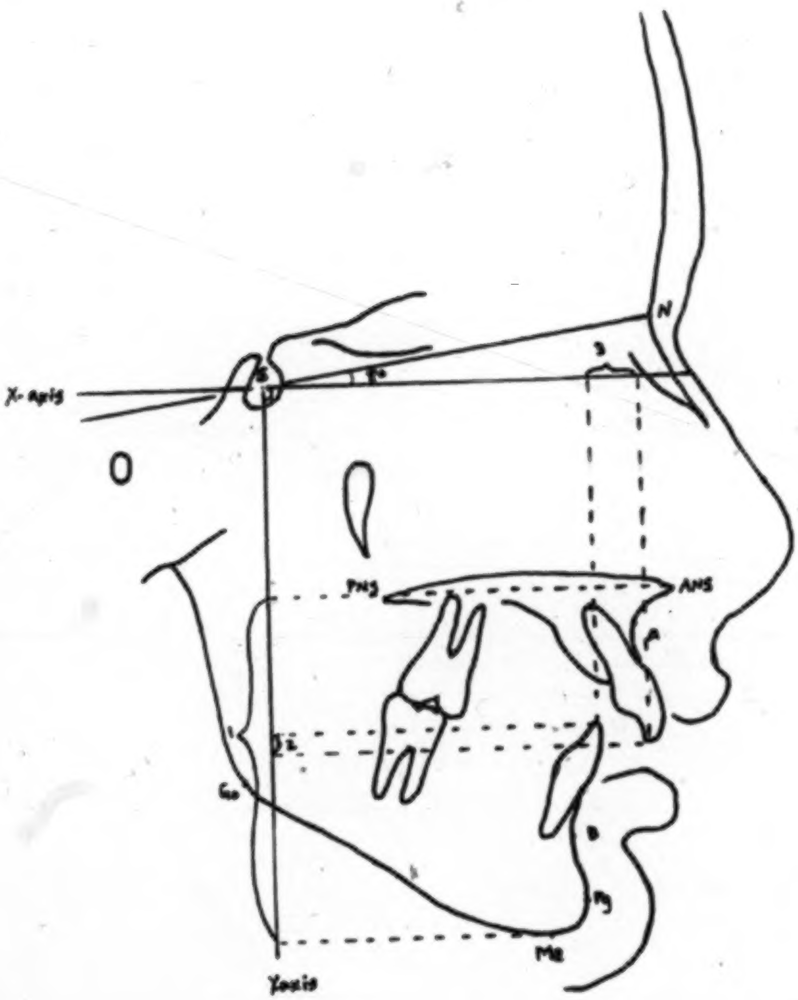
Table 5.1 Cephalometric Landmark Identification Definitions

Landmark	Identification Parameters
Sella (S)	The center of sella turcica
Nasion (N)	The suture between the frontal and nasal bones at the most posterior point on the curvature of the bridge of the nose
anterior nasal spine (ANS)	The anterior point of the Maxilla
posterior nasal spine (PNS)	The posterior point of the Maxilla
A-point (A)	The most posterior point on the curvature of the anterior Maxilla
B-point (B)	The most posterior point on the curvature of the anterior Mandible
Pogonion (Pg)	The most anterior point on the curvature of the bony chin
Gnathion (Gn)	The point bisecting the curvature at the anterior mandibular symphysis
Menton (Me)	The most inferior point at the mandibular symphysis
Gonion (Go)	The point bisecting the curvature of the angle of the Mandible
Mx 1	Maxillary incisor cusp tip
Md 1	Mandibular incisor cusp tip
Mx 6	Maxillary first permanent molar furcation point
Md 6	Mandibular first permanent molar furcation point

Linear measurements were obtained using a constructed grid as described by Mamandras and Allen (1990). The horizontal reference line was eight degrees from Sella-Nasion, approximating Frankfort Horizontal. The vertical reference was a line drawn perpendicular to the horizontal reference line, passing through Sella. This provided a convenient method for measuring vertical and anterior posterior landmark position changes by comparing the pretreatment to post treatment difference in x,y landmark coordinates. A positive value was assigned to landmark coordinates located anterior and inferior to the reference lines.

Figure 5.2 Distance Measurements

1) Lower face height 2) Overbite 3) Overjet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3
S
7°
X-axis
O
PNS
ANS
A
1
2
Go
B
Pg
Me
Y axis

Table 5.2 Distances Definitions for Landmark Distances and Calculated Measurements

Measurement	Definition
PNS vertical	vertical distance between PNS and the constructed x-axis
PNS horizontal	horizontal distance between PNS and the constructed y-axis
ANS vertical	vertical distance between ANS and the constructed x-axis
ANS horizontal	horizontal distance between ANS and the constructed y-axis
A point vertical	vertical distance between A point and the constructed x-axis
A point horizontal	horizontal distance between A point and the constructed y-axis
B point vertical	vertical distance between B point and the constructed x-axis
B point horizontal	horizontal distance between B point and the constructed y-axis
Pg vertical	vertical distance between Pg and the constructed x-axis
Pg horizontal	horizontal distance between Pg and the constructed y-axis
Gn vertical	vertical distance between Gn and the constructed x-axis
Gn horizontal	horizontal distance between Gn and the constructed y-axis
Me vertical	vertical distance between Me and the constructed x-axis
Me horizontal	horizontal distance between Me and the constructed y-axis
Mx 1 vertical	vertical distance between Mx 1 and the constructed x-axis
Mx 1 horizontal	horizontal distance between Mx 1 and the constructed y-axis
Md 1 vertical	vertical distance between Md 1 and the constructed x-axis
Md 1 horizontal	horizontal distance between Md 1 and the constructed y-axis
Mx 6 vertical	vertical distance between Mx 6 and the constructed x-axis
Mx 6 horizontal	horizontal distance between Mx 6 and the constructed y-axis

Md 6 vertical	vertical distance between Md 6 and the constructed x-axis
Md 6 horizontal	horizontal distance between Md 6 and the constructed y-axis
PFH : AFH	The ratio of the distance from Sella to Gonion to the distance from Nasion to Menton
Overbite	The vertical difference between the mandibular incisor cusp tip and the maxillary incisor cusp tip on the reference grid
Overjet	The horizontal distance between the maxillary and mandibular incisor cusp tips on the reference grid
Lower Face Height (LFH)	The vertical distance on the reference grid between ANS and Menton

Conventional angular measurements (Figure 5.3 and Table 5.3) were also obtained to demonstrate relational change in facial pattern. Rotational change of the long axis of the incisors and molars relative to the respective jaw bases were measured. The long axis of the molars was defined as being perpendicular to a line joining the mesial and distal heights of contour of the crown, taken through the furcation point of the tooth.

Figure 5.3 Angular Measurements

1) ANB 2)SNA 3)SNB
4) maxillary incisor to palatal plane
5) mandibular incisor to mandibular plane
6) maxillary molar to maxillary plane
7) mandibular molar to mandibular plane

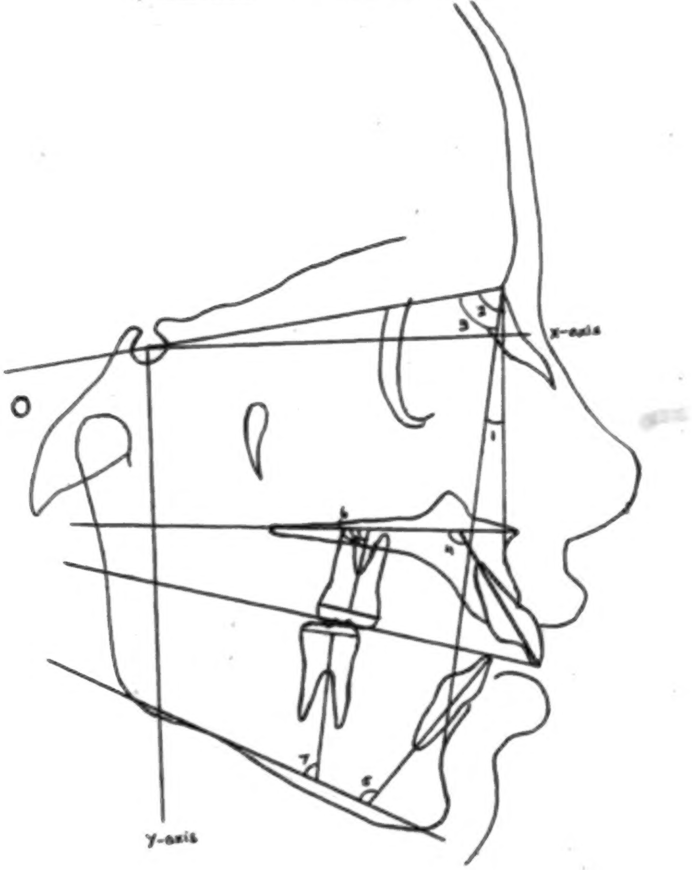

Table 5.3 Angular Measurement Definitions

Measurement	Definition
Mx 1 to Mx Plane	The angle of the maxillary central incisor to the maxillary plane
Mx 6 to Mx Plane	The angle of the maxillary first molar to the maxillary plane
Md 1 to Md Plane	The angle of the mandibular central incisor to the mandibular plane
Md 6 to Md Plane	The angle of the mandibular first molar to the mandibular plane
Occlusal Plane	The best fit of a line through the premolar and molar teeth to the horizontal axis of the reference grid.
Palatal Plane	The line between ANS and PNS to the horizontal axis of the reference grid
Mandibular Plane	The line between the points menton and gonion to the horizontal axis of the reference grid.
Y-axis	The angle between Sella-Nasion line and Sella-Gnathion

Superimposition of the mandible was performed to better visualize the tooth movements with respect to the body of the mandible (Figure 5.4 and Table 5.4). The cephalograms were partially traced with 0.5mm HB pencil on acetate tracing paper to allow superimposition of the mandible on anatomic structures. The horizontal and vertical reference lines from the initial cephalogram were transferred to the tracing. The internal anatomy at the symphysis and the mandibular canal were used to determine the orientation of the superimposition as this has been reported to be the most consistent with implant studies in approximating the true orientation (Springate and Jones, 1998). The tracings were then scanned and digitized.

Figure 5.4 Mandibular Superimposition Measurements

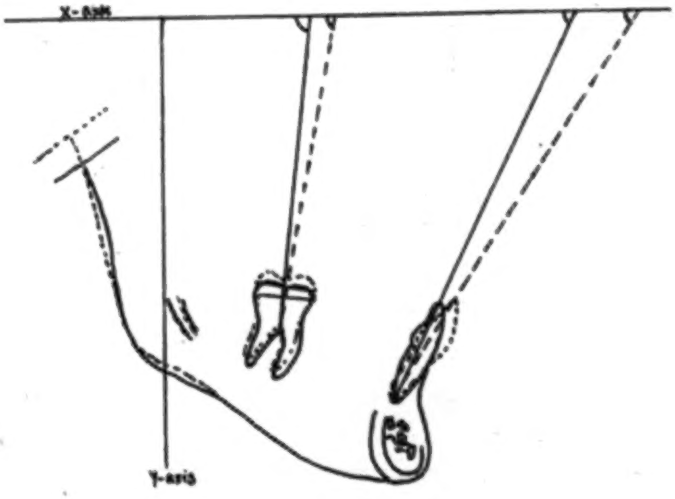

Table 5.4 Superimposition Measurement Definitions

Measurement	Definition
Md 1 horizontal	The horizontal distance of the mandibular incisor cusp tip from the vertical reference axis
Md 1 vertical	The vertical distance of the mandibular incisor cusp tip from the horizontal reference axis
Md 1 angulation	The angle of the mandibular incisor to the horizontal axis of the reference grid
Md 6 horizontal	The horizontal distance of the mandibular first molar furcation point from the vertical reference axis
Md 6 vertical	The vertical distance of the mandibular first molar furcation point from the horizontal reference axis
Md 6 angulation	The angle of the mandibular molar to the horizontal axis of the reference grid

Pilot studies were performed to investigate the error associated with the technique for analysis. The scanned and digitized cephalograms yielded reliability measurements of 0.98 or better for all of the landmarks used in this study. The mean error associated with the linear and angular measurements was less than 1.0 mm or 1.0 degrees for all measures except the tooth angulations which were less than 1.5 degrees. The superimposition tracing gave slightly higher error values with the distance measurements having a mean error of less than 1.0mm and the angular measurements having mean errors of approximately 2 degrees. The reliability for these measures was better than 0.82 for all measurements except the molar vertical which was 0.76. The action of superimposition tracing increased the error associated with these measurements but they are still valuable in clarifying the movements of the teeth with in the lower jaw by removing the influence of the changes occurring elsewhere in the face.

All digitizations were repeated twice for each cephalogram and tracing and checked for accuracy. Where discrepancies of more than 2 mm or 2 degrees were found a third digitization was performed to determine the most accurate values. The duplicate measurements were then averaged to provide the data for analysis.

The groups were compared for pretreatment equivalence of all measurements using unpaired t-tests. The analysis was carried out with t-tests after checking that the measurements appeared to follow a normal distribution. The assumption of equality of the standard deviations was not valid for many of the measurements so this was adjusted for in the calculation of the statistic. The difference in the measured values over the treatment time (ie: time two measurement minus the time one measurement) were then compared also with the same types of t-tests, to explore the differences in the effects of the two treatment protocols.

5.3 Results

The two treatment groups were compared to determine if there were any differences in group composition. The groups were not statistically different in terms of age, gender, or length of treatment (Table 5.5 and 5.6).

Table 5.5 Group Composition Characteristics

	TREATMENT GROUP	MEAN	STD. DEVIATION	MEAN DIFFERENCE	P-VALUE (2-TAILED)
age at time 1 (months)	*1	108.6	12.21	-2.2	0.627
	**2	110.8	14.10		
sex	1	1.56	0.502	-0.02	0.896
	2	1.58	0.515		
treatment duration (months)	1	14.6	4.75	1.6	0.206
	2	13	3.36		

*1=deep group; **2=open group; ^ significant at $p<0.05$; ^^ significant at $p<0.01$

Table 5.6 Group Composition for Gender

		treatment group	
		deep	open
SEX	male	18 (44%)	5 (42%)
	female	23 (56%)	7 (58%)
Total		41 (100%)	12 (100%)

Pretreatment differences

Skeletal Measurements

There were some differences in the pretreatment skeletal measurements for the two groups (Table 5.7). The mandibular vertical measurements at B point, Pogonion, Gnathion and Menton, show that the anterior region of the mandible is in a lower vertical position in the open group by approximately 3.4mm ($p \leq 0.005$). The lower mandibular position also corresponded with a larger lower face height 4.09mm greater ($p=0.000$), in this group prior to treatment.

Table 5.7 T-tests of Pretreatment Skeletal Measurements

	Treatment Group	Mean	Std. Deviation	Mean Difference (deep – open)	p-value (2-tailed)
Vertical					
PNS (mm)	*1	37.143	1.978	-0.371	0.688
	**2	37.514	2.944		
ANS (mm)	1	37.475	2.790	0.734	0.414
	2	36.741	2.641		
A (mm)	1	41.750	2.716	0.958	0.267
	2	40.792	2.504		
B (mm)	1	73.391	3.709	-3.730	0.003
	2	77.121	3.293		
PG (mm)	1	85.363	4.261	-3.830	0.002
	2	89.194	3.093		
GN (mm)	1	88.672	4.024	-3.419	0.004
	2	92.090	2.950		
ME (mm)	1	90.610	4.012	-3.358	0.005
	2	93.968	3.072		
LFH (mm)	1	53.142	3.435	-4.095	0.000
	2	57.237	2.521		
PFH:AFH	1	0.634	0.034	-0.005	0.665
	2	0.638	0.032		
Horizontal					
PNS (mm)	1	20.227	3.368	-0.154	0.882
	2	20.381	3.033		
ANS (mm)	1	66.397	4.427	-0.399	0.803
	2	66.796	4.913		
A (mm)	1	63.038	4.469	-0.937	0.584
	2	63.975	5.277		
B (mm)	1	52.587	6.237	-0.487	0.825
	2	53.074	6.730		
PG (mm)	1	52.382	7.069	-0.549	0.821
	2	52.931	7.360		
GN (mm)	1	50.910	7.341	-0.728	0.763
	2	51.638	7.200		
ME (mm)	1	48.109	7.337	-1.063	0.652
	2	49.171	6.981		
Angular					
ANB (degrees)	1	6.618	1.734	-0.010	0.987
	2	6.628	1.915		
SNA (degrees)	1	80.548	3.417	-0.162	0.899
	2	80.710	3.956		
SNB (degrees)	1	73.931	3.234	-0.151	0.885
	2	74.083	3.114		
Palatal plane (degrees)	1	0.445	2.983	1.348	0.195
	2	-0.903	3.072		
Mandibular plane (degrees)	1	26.790	4.456	-0.144	0.926
	2	26.933	4.703		

Y-axis (degrees)	1	68.215	4.070	-0.580	0.639
	2	68.795	3.598		

*1=deep group; **2=open group

Dental Measurements

There were selected differences in the pretreatment dental measurements (Table 5.8). The overbite is of course significantly different (5.69mm mean difference; p=0.000) as this was the basis of selection for the groups. The mandibular incisor is lower in the open group 4.18mm (p=0.001) as is the maxillary molar 2.01mm (p=0.009), both of these likely contributing to the difference in overbite. The overjet also happens to be greater in the open group by 1.73mm (p=0.005).

Table 5.8 T-tests of Pretreatment Dental Measurements

	Treatment Group	Mean	Std. Deviation	Mean Difference (deep - open)	p-value (2-tailed)
Vertical					
Mx 1 (mm)	*1	62.705	3.312	1.517	0.185
	**2	61.188	3.367		
Md 1 (mm)	1	56.698	2.904	-4.177	0.001
	2	60.875	3.164		
Mx 6 (mm)	1	44.015	2.941	-2.006	0.009
	2	46.022	1.887		
Md 6 (mm)	1	61.492	3.255	-1.359	0.132
	2	62.851	2.453		
overbite (mm)	1	6.011	1.217	5.693	0.000
	2	0.318	1.407		
Horizontal					
Mx 1 (mm)	1	65.387	5.592	-2.038	0.299
	2	67.425	5.852		
Md 1 (mm)	1	58.580	5.705	-0.311	0.871
	2	58.891	5.795		
Mx 6 (mm)	1	33.180	4.100	-0.400	0.770
	2	33.581	4.118		
Md 6 (mm)	1	24.905	4.665	-1.296	0.416
	2	26.200	4.760		
overjet (mm)	1	6.804	2.356	-1.726	0.005
	2	8.530	1.474		
Angular					
occlusal plane (degrees)	1	12.679	5.246	0.359	0.792
	2	12.320	3.716		
Mx 1 to Mx plane (degrees)	1	110.914	7.964	-1.715	0.416
	2	112.629	5.749		
Md 1 to Md plane (degrees)	1	96.121	6.779	0.172	0.951
	2	95.949	8.791		
Mx 6 to Mx plane (degrees)	1	64.138	3.578	1.274	0.381
	2	62.865	4.487		
Md 6 to Md plane (degrees)	1	78.615	4.358	0.480	0.742
	2	78.136	4.379		

*1=deep group; **2=open group

Treatment Effects

Skeletal Measurements

There were significant differences in the skeletal changes between the two treatment groups (Table 5.9). The mandibular points B point, Pogonion, Gnathion, and Menton are all significantly lowered vertically by 2-3mm in the deep group as compared to the open. Change in y-axis and mandibular plane was significantly different between the two treatment groups. The deep bite group showed slight increase while the open bite group showed a slight decrease with the net difference being about 1 to 1.5 degrees between the two groups. These factors combine to provide a highly significant 2.4mm greater increase in lower face height for the deep group.

There were no significant differences between the deep bite and open bite groups in pretreatment to post treatment change in any horizontal measurements.

Table 5.9 Skeletal Measurements Changes with Treatment

	Treatment Group	Mean	Std. Deviation	Mean Difference (deep - open)	p-value
Vertical					
PNS (mm)	*1	0.851	0.678	-0.301	^0.275
	**2	1.152	0.846		
ANS (mm)	1	1.336	1.638	-0.055	^0.896
	2	1.391	1.135		
A (mm)	1	1.205	1.888	-0.630	^0.196
	2	1.835	1.292		
B (mm)	1	5.432	2.223	2.969	^^0.000
	2	2.464	1.712		
PG (mm)	1	5.594	2.165	2.401	^^0.001
	2	3.193	1.725		
GN (mm)	1	5.422	1.907	2.303	^^0.000
	2	3.119	1.541		
ME (mm)	1	5.295	1.803	2.291	^^0.000
	2	3.004	1.548		
LFH (mm)	1	3.993	1.490	2.391	^^0.000
	2	1.602	1.354		
PFH:AFH	1	0.001	0.017	0.010	^0.056
	2	-0.008	0.014		
Horizontal					
PNS (mm)	1	0.266	1.665	0.148	^0.785
	2	0.118	1.821		
ANS (mm)	1	0.245	1.767	-0.521	^0.336
	2	0.766	1.562		
A (mm)	1	0.042	1.396	-0.004	^0.993
	2	0.045	1.278		
B (mm)	1	2.667	2.743	-1.026	^0.177
	2	3.693	2.079		
PG (mm)	1	2.480	3.151	-1.380	^0.101
	2	3.861	2.235		
GN (mm)	1	2.463	3.143	-1.467	^0.088
	2	3.930	2.297		
ME (mm)	1	2.569	3.164	-1.376	^0.111
	2	3.945	2.313		
Angular					
ANB (degrees)	1	-2.505	1.336	0.338	^0.411
	2	-2.843	1.192		
SNA (degrees)	1	-0.827	1.538	-0.116	^0.774
	2	-0.712	1.102		
SNB (degrees)	1	1.704	1.737	-0.435	^0.342
	2	2.139	1.237		
Palatal plane (degrees)	1	0.615	1.936	0.260	^0.554
	2	0.355	1.080		
Mandibular plane (degrees)	1	0.979	2.060	1.532	^^0.003
	2	-0.553	1.230		

Y-axis (degrees)		1	0.253	1.960	1.257	^0.013
		2	-1.005	1.266		

*1=deep group; **2=open group
^ two tailed p-value; ^^ one tailed p-value

Dental Measurements

There were significant differences in dental changes with the two treatments (Table 5.10). The overbite opened by 3.99mm in the deep treatment group and closed by 0.7mm in the open group. This gave a mean difference of 4.69mm which was highly significant (p=0.000). The maxillary incisor moved significantly differently in these two groups. The open group showed a 0.9mm greater downward vertical movement of the maxillary incisor cusp tip. The mandibular incisor also gave a significantly different vertical change between these groups. The deep group showing a 6.37mm lowering of the vertical position of this incisor cusp tip. This is partially related to the significant change in the angulation of this tooth with the deep group having proclined 2.9 degrees more than the open bite group. It is also due to the significant differences in the skeletal changes (lowering the vertical position of the anterior mandible). The occlusal plane reflects the vertical changes in the dental and skeletal landmarks with a differential steepening in the deep group of 3.9 degrees.

The mandibular superimposition was used to aid in clarification of the dental changes in this jaw with the skeletal effects removed (Table 5.8). The superimposition results show significant differences in the movements of the lower incisor and molar. The lower incisor proclines in both groups but 3.5 degrees more in the deep group. The cusp tip of the lower incisor is more forward and more downward by 0.7mm and 0.8mm respectively in this group. The molar is higher vertically by 1.2mm in the deep group with no difference in the change in angulation between groups.

There are few statistically significant differences horizontally in the dental measures. On the superimposition analysis the mandibular incisor moves more forward by 0.7mm in the deep group and proclines 3.5 degrees more in this group (both measures $p<0.05$). Other trends are the change in overjet which showed about 1mm greater reduction $p=0.097$ in the open group. There was also a trend toward greater retroclination of the maxillary incisors in this group by about 3.3 degrees $p=0.067$. There was a trend toward more forward movement of the mandibular molar from the superimposition analysis in the deep group of 0.6mm with $p=0.051$.

Table 5.10 Dental Measurements Changes with Treatment

	Treatment group	*Mean*	*Std. Deviation*	*Mean Difference (deep - open)*	*p-value*
Vertical					
Mx 1 (mm)	*1	2.390	1.910	-0.908	^^0.024
	**2	3.298	1.129		
Md 1 (mm)	1	6.370	2.147	3.778	^^0.000
	2	2.592	1.597		
Mx 6 (mm)	1	0.852	1.433	0.003	^0.996
	2	0.849	1.442		
Md 6 (mm)	1	3.601	1.477	-0.034	^^0.467
	2	3.635	1.170		
Overbite (mm)	1	-3.988	1.657	-4.690	^^0.000
	2	0.702	1.219		
Horizontal					
Mx 1 (mm)	1	-0.450	2.894	1.096	^0.169
	2	-1.547	2.173		
Md 1 (mm)	1	4.444	2.650	-0.093	^0.883
	2	4.537	1.619		
Mx 6 (mm)	1	-0.083	1.648	0.048	^0.933
	2	-0.132	1.759		
Md 6 (mm)	1	4.309	2.629	0.211	^0.797
	2	4.098	2.422		
Overjet (mm)	1	-4.891	2.373	1.188	^0.097
	2	-6.079	1.991		
Angular					
Occlusal Plane (degrees)	1	3.874	3.784	3.914	^^0.000
	2	-0.040	2.566		
Mx 1 to Mx Plane (degrees)	1	-1.981	7.326	3.328	^0.067
	2	-5.310	4.573		
Md 1 to Md Plane (degrees)	1	4.588	4.174	2.898	^0.011
	2	1.690	2.863		
Mx 6 to Mx Plane (degrees)	1	-6.263	5.887	-2.331	^0.284
	2	-3.932	6.555		
Md 6 to Md Plane (degrees)	1	-2.681	5.077	0.147	^0.936
	2	-2.829	5.628		

*1=deep group; **2=open group

^ two tailed p-value; ^^ one tailed p-value

Table 5.11 Mandibular Superimposition Changes with Treatment

	Treatment Group	Mean	Std. Deviation	Mean Difference (deep - open)	p-value (2-tailed)
Md 1 horizontal (mm)	*1	2.025	1.211	0.740	^0.017
	**2	1.285	0.775		
Md 1 vertical (mm)	1	-0.769	1.297	-0.831	^0.029
	2	0.062	1.013		
Md1 angulation (degrees)	1	-6.152	4.288	-3.488	^^0.002
	2	-2.664	2.784		
Md 6 horizontal (mm)	1	1.674	1.270	0.634	0.051
	2	1.040	0.828		
Md 6 vertical (mm)	1	1.535	1.060	1.161	^^0.004
	2	0.374	1.081		
Md 6 angulation (degrees)	1	1.045	5.811	0.472	0.711
	2	0.572	3.060		

*1=deep group; **2=open group; ^ significant at $p<0.05$; ^^ significant at $p<0.01$

5.4 Discussion

The aim of Phase I treatment with growth modification is to correct the skeletal and dental relationships. This goal - the correction of the anteroposterior Class II relationship and achievement of normal overbite and overjet - defines the end point of treatment. While aiming for the same endpoints, the treatment groups in this study had considerably different starting malocclusions yet the two treatment protocols appear effective in controlling the necessary parameters to achieve the goal.

The patients in this study were finished with mean ANB angle of 4.1degrees for the deep bite group and 3.8 for the open bite group and overjets of 1.9mm and 2.5mm respectively. Neither of these values are statistically or clinically significantly different. The observation that there was a trend for the open group to experience a greater overjet correction is likely an artifact of the pretreatment difference. A significant pretreatment difference when treated to essentially the same endpoint will reappear as a significant change simply because both groups are fully treated. The overbites post-treatment are almost statistically significantly different (p=0.055) but not clinically significantly different. The deep bite group finished with a 2.0mm mean overbite and the open group finished with 1.0mm mean overbite. The many skeletal and dental changes that occur with treatment seem to combine in the right manner to produce the desired outcome for both treatment groups. The skeletal differences are dramatically different in the vertical and horizontal components. The deep bite treatment moves the mandible down vertically generating a modest but statistically and clinically significant differential increase in lower face height of about 2.4mm. This also contributes to small changes in the y-axis and mandibular plane angles with both increasing slightly. These changes are too small to be considered clinically significant but they do show changes in a beneficial direction. In the horizontal dimension there were no differences in any of the skeletal measurements for the two groups. This indicates that the influence of the appliance in the anteroposterior dimension was unaffected by the modifications designed for the vertical changes.

The difference in the dental changes were most numerous for the incisors. The maxillary and mandibular incisor cusp tips were moved differentially. The open group had the maxillary incisor move down vertically by 0.9mm more than the deep group while the lower incisor moved down vertically 0.8mm more in the deep bite group than the open. These movements combined to create a more normalized over bite for both groups. Considering only these significant dental changes the differential change in overbite would be 1.7mm. This indicates the large contribution of the skeletal changes in the deep group to reduce the overbite as the true differential change in overbite between the two groups was 4.7mm. The deep experienced 3.99mm of reduction in overbite while the open group closed 0.7mm.

The difference in the overbite for the deep bite group is clinically impressive but the change for the open bite group is less so. It should be noted that the open bite group was based on a cutoff criteria of bite depth less than 2mm on the pretreatment cephalogram. About half of the patients in this group had overbites between 1 and 2 mm at time one; that is they were clinically within normal range of overbite. It is possible that these patients may have had less emphasis on construction of the appliance to a vertical dimension exceeding their natural freeway space.

The molars did not move differently between the two groups on the overall measurements but when the mandibular superimposition removes the effects of changes elsewhere in the face the differences in mandibular molar movement become apparent. The molar moved more forward by 0.6mm and erupted 1.2mm more in the deep group. These amounts are small but do indicate a relationship in the anteroposterior and vertical correction that was suspected. The small amount of added eruption of the molar generates a very significant anterior contribution to the change in overbite and the increased lower face height due to the hinge effect of the mandible.

The dental measurements also demonstrated differences in the change in the angulation of the lower incisor. The deep bite group had a greater proclination of the lower incisor by about 3 degrees. This may be due to the anterior component of the molar eruption contributing to the mesialization of the mandibular dentition in this group. The deep group does appear to have significantly more mesial movement of the mandibular dentition. The amount is small however at less than 1mm and thus the horizontal skeletal changes are not significantly different for the two treatment groups.

The twin block appliance as used in this study to correct a deep overbite or preserve a shallow overbite seems to generate a similar anteroposterior correction in both the skeletal and dental parameters. The correction of the deep bite appears efficiently addressed while the shallow overbite is not opened with appropriate treatment. The dental compensation that occurs with this appliance appears to be slightly greater in the group treated to increase the vertical dimension. This may be related to the greater anterior movement of the mandibular molar as it is permitted to erupt. The twin block appliance corrects the vertical aspect of the malocclusion both dentally and skeletally as it has been shown to do in previous investigations of the anteroposterior corrections.

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Chapter 6

General Discussion

6.1 Introduction

The purpose of this thesis is to investigate the dental and skeletal effects of the twin block appliance on the vertical dimension. This is a retrospective study of two different treatment protocols which were used to alter the vertical aspect of patients' malocclusions at the same time that the anteroposterior correction was undertaken.

The vertical dimension is often one of the most challenging aspects of a malocclusion to correct. It can complicate the correction of a Class II relationship for both horizontal and vertical skeletal pattern patients. In particular the combination of Class II malocclusion and vertical skeletal growth pattern can be beyond the range of correction with orthodontics alone and surgery is required. While patients with horizontal type growth patterns benefit from downward movement of the mandible to correct the shortened lower facial height, at the same time this swings the mandible backward worsening the Class II relationship.

The twin block appliance has gained popularity recently for correction of Class II malocclusions. This appliance has been used by the practitioner supplying the cases to effectively manage the vertical dimension while still generating the necessary anteroposterior correction. This ability to alter the vertical component of a malocclusion while creating anteroposterior change is an advantage in the efficiency of phase I treatment. This advantage invites investigation to look at how the correction of the vertical is accomplished as well as what if any interaction may be occurring with the vertical and anteroposterior correction. The speculation that this appliance, like other functional appliances, may alter the growth of the facial skeleton to reduce the severity of the skeletal discrepancy is also very appealing. The hope would be that such skeletal changes in the vertical dimension might be more stable than simply dental changes. This study does not attempt to determine the long term effects of treatment with the twin block appliance but it does endeavor to explore the immediate changes that are apparent after treatment.

6.2 Major Conclusions

The major findings from this investigation relate to the convincing ability of the treatment protocols to produce the desired changes in the vertical dimension while still producing very efficient saggital correction of moderate to severe Class II malocclusions. The data in this study indicate that when the twin block appliance is used with the bite blocks adjusted throughout treatment to allow eruption of the mandibular molar, the lower face height is increased by about 2.4mm and the overbite is reduced by about 4.0mm. If the second protocol is followed where there is no adjustment of the vertical height of the bite blocks during treatment the lower face height and overbite are not significantly changed. These effects are seen to occur simultaneously with similar correction of overjet between the two treatment groups.

The first study isolated the change in overbite and investigated the ability of the treatment to successfully change the overbite as compared to a control group. The deep bite treatment was successful in creating a significant difference in the overbite as compared to their control group. The open bite group did not show significant difference in the change in overbite as compared to their control group. The lack of difference in the open bite group limited the ability to explore the treatment results in a more in depth way for this treatment protocol. It was unfortunate that the group size was so small. Perhaps a larger sample would have generated data that could have been more revealing.

The overbite correction that was observed for the deep bite group was then studied in order to reveal the contribution of the various skeletal and dental components involved in the correction. Regressions were used to explore the factors dentally and skeletally responsible for the outcome of the change in overbite. The major factors identified by the regressions for the change in overbite were the restriction of maxillary molar eruption, restriction of mandibular incisor eruption and the lowered position of the anterior mandible. It was very difficult to identify and interpret the responsible factors as many of the dental changes influenced the skeletal movements and vice versa. For example, the significant increase in lower face height that is the single factor identified as the most responsible for the change in overbite occurs presumably due to an increased posterior dental eruption but the movements of the molar teeth themselves are substantially less significant. This occurs partially because the small movements in the posterior dentition are amplified in the anterior face due to the hinging effect of the mandible. The regression should be able to discern this. It may be that the vertical and horizontal changes in the molar positions on the occlusal plane are all contributing small amounts. The small up and back movement of the maxillary molar and the small forward and down movement of the mandibular molar are preventing any single factor from standing out. The regressions seem to indicate that the small changes in multiple landmarks are all vital in creating the outcome. These findings are in agreement with Naumann, Behrents and Buschang (2000) in their investigation of the normal changes in overbite. They found that on average only very small amounts of overbite change were seen in non-treated subjects between the ages of 10 and 15 years. In attempting to identify the components responsible for the observed changes it was impossible to identify single variables that accounted for any large portion. When they used a multivariate approach the mandibular vertical growth and lower incisor eruption were determined to be the most important variables.

T-tests were used to explore many individual dental and skeletal changes in facial landmarks for both papers. There were determined to be significant differences between the compared groups for many of the variables. The mean differences in most of the landmarks are small values and the pilot studies indicate that the mean and maximum errors likely for these measurements is large proportionately and it is with caution that these values are considered. In particular the angular measurements of the dentition and the mandibular superimposition values demonstrated higher error values. The summary measurements of overbite, overjet and lower face height were found to be quite accurate and the substantial changes observed here indicate that the treatment protocols were successful in the desired outcome.

The second paper compares the deep bite treatment directly to the open bite protocol. The purpose of this comparison is to demonstrate the difference between the two treatments. The findings of this paper indicate that both treatment methods are efficient in correction of the Class II relationship and the treatments do differ in their vertical results. The deep bite treatment is successful in opening the bite and the open bite treatment does not change the bite depth. The vertical differences do appear to impact the horizontal correction slightly with a greater mesialization of the mandibular dentition in the deep bite group.

6.3 Limitations

This study is a retrospective observational design and as such has many limitations. The retrospective nature of the study means that the delivery of treatment was uncontrolled. The need for division of patients into groups for analysis lead to the generation of cutoff criteria for the pretreatment overbite. This criteria resulted in some groups with very small numbers. In paper 1 these small sample sizes limited the power of the statistical investigation. The power was evaluated as only 27.6% for the ability to detect a 1.9mm difference in overbite for the open bite treatment and control groups with the numbers in this group and the standard deviation present. The small numbers would also have restricted the number of variables that could be investigated in a regression analysis had a difference in the overbite been found.

The lack of pretreatment equivalence is also an important consideration in paper 1. The treatment groups had more significant malocclusions than the control groups even though the most severe cases available from the growth study were selected. It may be that the control and treatment groups would have grown differently due to the discrepancy in the severity of the Class II relationship. The differences in the ages and the length of time between radiographs for the open bite treatment and control groups was also significant. These groups might show difference due to these important factors as well.

The patients in the control group also belong to a different population. The Bolton-Brush growth study was conducted from the 1930's to the 1950's on children in the Cleveland, Ohio area, while the treatment groups are composed of children treated within the last ten years that living in Vancouver, British Columbia. Particularly important in this respect might be an effect of the general increasing size of the population in North America over the past 50 to 100 years. This effect while probably present is also probably not large. The retrospective design of this study and the need to find a control group to compare to also created limitations to the scientific design of the data gathering. The lateral cephalograms had obviously been taken on different machines and it was impossible to trace or digitize the radiographs without knowledge of the group to which the radiograph belonged. All of the measurements in this study are included in this limitation, the overall measurements as well as the measurements for the superimpositions. This is a large sacrifice in the proper scientific method to rigorously test the questions of interest. The older cephalostat design used for the growth study films also prevented the investigation of some measurements which were of interest. It may have been enlightening to look at the positional changes of articulari and to investigate the changes in the angular measurements for the articular and gonial angles. The gonial angle was particularly of interest as previous researchers had found significant changes there when using bite blocks to treat open bite cases. (Iscan and Sarisoy, 1997).

6.4 Future Study

A prospective randomized clinical trial would of course be the most desirable type of study to further investigate the effects of this appliance. Ideally the patients would be assigned randomly to treatment or control and the treatment group would be further selected to undergo the deep or open protocol based on the presentation of initial bite depth. This would remove many of the limitations associated with the current study. The ideal situation would have larger sample sizes such that three skeletal vertical categories -

horizontal, neutral and vertical - could be examined and statistical analysis could determine the degree of influence the many small dental and skeletal changes have on the outcome of treatment. It would be very interesting to look at the changes produced by the two different treatment protocols on the various skeletal patterns. Using a post hoc power analysis the sample size would need to be about 21 to 35 patients per group to allow power of 70 to90% respectively for the standard deviations and differences detected in this study. The study would be immediately post treatment with a long term follow up after phase two and completion of growth. Any study that might follow is likely to only address some of the design aspects considered here. It would be enlightening to follow this treatment group to see how well the treatment changes are maintained through growth. This is especially interesting for this group as they have been treated at relatively young ages and have a long period over which the previous growth pattern might re-express itself.

6.5 References

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